Agilent Technologies E1472A/73A/74A/75A 50 Ohm and 75 Ohm RF Multiplexers/Expanders User's Manual

Agilent Technologies

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E1472A/73A/74A/75A RF Multiplexers User's Manual
Edition 4
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Documentation History

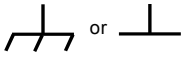
All Editions and Updates of this manual and their creation date are listed below. The first Edition of the manual is Edition 1. The Edition number increments by 1 whenever the manual is revised. Updates, which are issued between Editions, contain replacement pages to correct or add additional information to the current Edition of the manual. Whenever a new Edition is created, it will contain all of the Update information for the previous Edition. Each new Edition or Update also includes a revised copy of this documentation history page.

Edition 1 . . . . . January, 1990
Edition 2 . . . . . October, 1991
Edition 3 . . . . . November, 1992
Edition 4 . . . . . November, 2000
Edition 4, Rev 1 . . . . . September 2012

Safety Symbols

Instruction manual symbol affixed to product. Indicates that the user must refer to the manual for specific WARNING or CAUTION information to avoid personal injury or damage to the product.

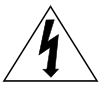
Indicates the field wiring terminal that must be connected to earth ground before operating the equipment — protects against electrical shock in case of fault.



Frame or chassis ground terminal—typically connects to the equipment's metal frame.

Alternating current (AC)

Direct current (DC).



Warning. Risk of electrical shock.

WARNING Calls attention to a procedure, practice, or condition that could cause bodily injury or death.

CAUTION Calls attention to a procedure, practice, or condition that could possibly cause damage to equipment or permanent loss of data.

WARNINGS

The following general safety precautions must be observed during all phases of operation, service, and repair of this product. Failure to comply with these precautions or with specific warnings elsewhere in this manual violates safety standards of design, manufacture, and intended use of the product. Agilent Technologies assumes no liability for the customer's failure to comply with these requirements.

Ground the equipment: For Safety Class 1 equipment (equipment having a protective earth terminal), an uninterruptible safety earth ground must be provided from the mains power source to the product input wiring terminals or supplied power cable.

DO NOT operate the product in an explosive atmosphere or in the presence of flammable gases or fumes.

For continued protection against fire, replace the line fuse(s) only with fuse(s) of the same voltage and current rating and type. DO NOT use repaired fuses or short-circuited fuse holders.

Keep away from live circuits: Operating personnel must not remove equipment covers or shields. Procedures involving the removal of covers or shields are for use by service-trained personnel only. Under certain conditions, dangerous voltages may exist even with the equipment switched off. To avoid dangerous electrical shock, DO NOT perform procedures involving cover or shield removal unless you are qualified to do so.

DO NOT operate damaged equipment: Whenever it is possible that the safety protection features built into this product have been impaired, either through physical damage, excessive moisture, or any other reason, REMOVE POWER and do not use the product until safe operation can be verified by service-trained personnel. If necessary, return the product to Agilent for service and repair to ensure that safety features are maintained.

DO NOT service or adjust alone: Do not attempt internal service or adjustment unless another person, capable of rendering first aid and resuscitation, is present.

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- Alternately, you can go to the product web page (www.agilent.com/find/E1472A), click on the Document Library tab then scroll down until you find the Declaration of Conformity link.

Notes:

Chapter 1
Getting Started

Using This Chapter

This chapter describes the RF Multiplexer and Expander modules and contains information on how to program them using Standard Commands for Programmable Instruments (SCPI). This chapter contains the following sections:

- How to Use This Manual. 9
- RF Multiplexers Description 10
- Programming the RF Multiplexers 13

How to Use this Manual

This manual shows how to operate, configure, and program the E1472A 50 Ohm RF Multiplexer, E1473A 50 Ohm RF Multiplexer Expander, E1474A 75 Ohm RF Multiplexer, and E1475A 75 Ohm RF Multiplexer Expander modules. The RF Multiplexer is a VXIbus C-Size register-based slave device, and can operate in a C-size VXIbus mainframe using a command module such as the E1406. For other manufacturers' mainframes, refer to the applicable manual supplied by the manufacturer.

NOTE *Except where noted, the term "RF Multiplexer" refers to the E1472A 50 Ohm RF Multiplexer and E1474A 75 Ohm RF Multiplexer Modules. The term "Expander" refers to the E1473A 50 Ohm RF Multiplexer Expander, and E1475A 75 Ohm RF Multiplexer Expander Modules.*

Most information in this manual applies to RF Multiplexer operations in a command module. Standard Commands for Programmable Instruments (SCPI) is the programming language. For non-SCPI programming, see Appendix B for register-based programming.

RF Multiplexers Description

Figure 1-1 shows the 50 Ohm and 75 Ohm RF Multiplexer and 50 Ohm and 75 Ohm RF Multiplexer Expander modules switching diagram. During power off, power on and reset, channel 0 is connected to COM on each bank.

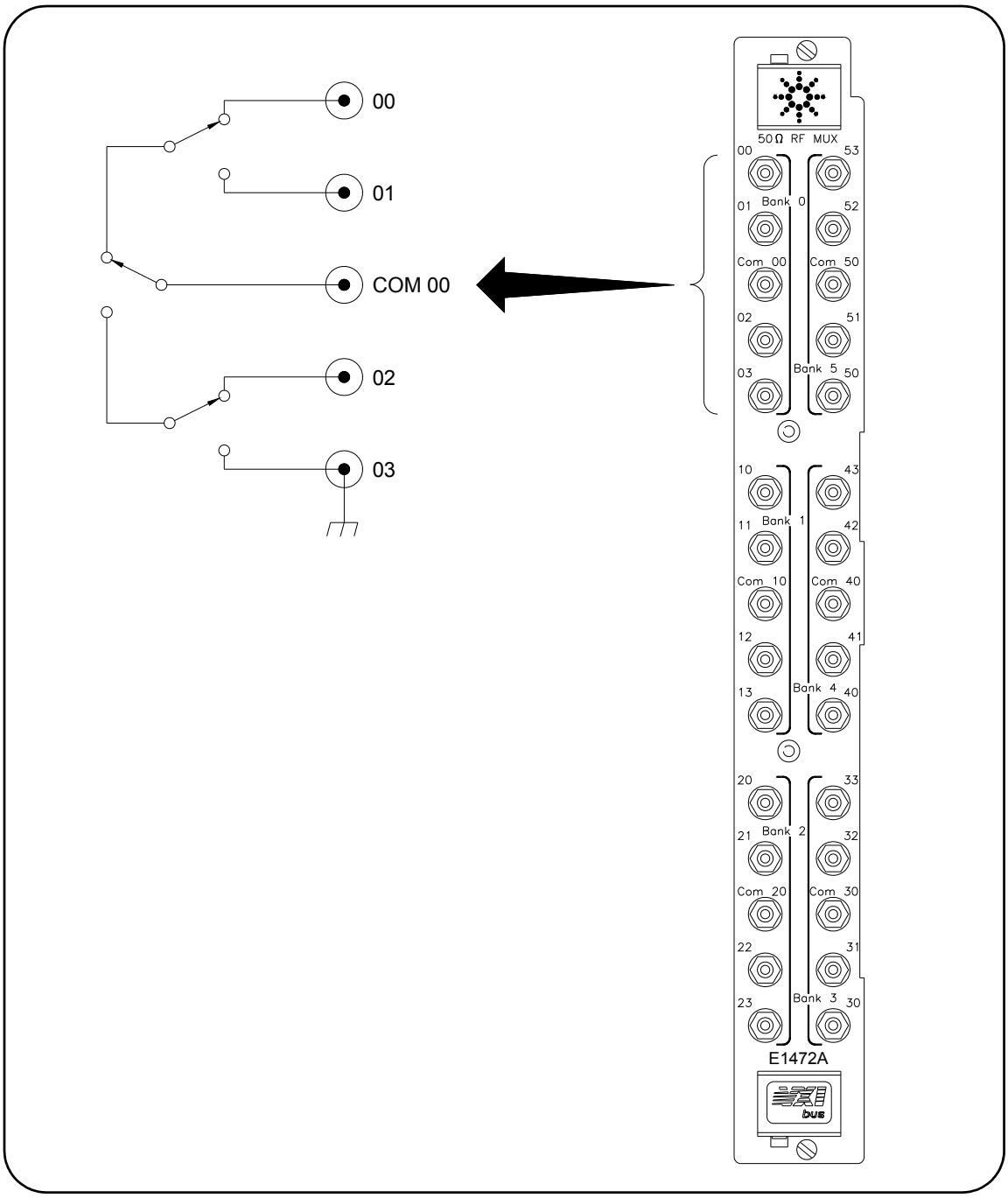

Figure 1-1. RF Multiplexers/Expanders Switching Diagram

General Description

The RF Multiplexer (6 x 4:1) and the Expander (6 x 4:1) modules are VXIbus C-Size register-based products which provide bidirectional switching for user inputs and outputs. Switching consists of connecting one channel to common in that bank. The RF Multiplexer can operate in a C-Size VXI mainframe using a command module such as an E1406.

Up to two Expander modules can be controlled by a single RF Multiplexer module, providing a total of eighteen (4:1) multiplexer banks. These Expander modules can either be inserted into the C-Size mainframe next to the RF Multiplexer, or can be located up to eight meters from the RF Multiplexer using the remote expander cables. Locating the Expander module close to the external device keeps connecting cable lengths to a minimum, thereby reducing the possibility of cross-talk and insertion loss of high frequency signals.

You may connect E1475A Expander or E1473A Expander to the E1472A or E1474A Multiplexer. The drivers on both modules can support either of the expander relay modules.

Basic Operation

The RF Multiplexer modules and Expander module consists of six banks of channels (bank 0 through bank 5) to form six 4:1 multiplexers. The switching sections of the RF Multiplexer and Expander modules are identical. See Figure 1-1 for a simplified switching diagram. Banks are arranged as follows:

- Bank 0 includes channels 00 through 03 and Com 00.
- Bank 1 includes channels 10 through 13 and Com 10.
- Bank 2 includes channels 20 through 23 and Com 20.
- Bank 3 includes channels 30 through 33 and Com 30.
- Bank 4 includes channels 40 through 43 and Com 40.
- Bank 5 includes channels 50 through 53 and Com 50.

In the remainder of this manual, channels are referred to as n0 through n3 and Com n0, where n is the bank number (0 through 5). Each channel is switched (connected to its common) by closing the appropriate (nonlatching) relays. Channels n0 through n3 can be switched to Com n0 for all banks. Only one channel in each bank can be connected to its common at a time.

User inputs/outputs to each channel are via SMB connectors. When a channel is CLOSed, it is internally connected to the COMmon connector. When a channel is open, it is internally disconnected. Open channels are not terminated. At power-off, power-on, or reset, channel n0 is switched to the COM n0 connector, and all other channels (n1 through n3) are open (non-terminated) for all banks.

Typical Configuration

The RF Multiplexer and Expander relays are configured in a “tree” structure which provides high isolation and low VSWR (voltage standing wave ratio). Each channel can switch user inputs up to 24 Watts (42V peak). User input frequencies to the 50 Ohm RF Multiplexer and Expander modules can be from DC to 3 GHz. User input frequencies to the 75 Ohm RF Multiplexer and Expander modules can be from DC to 1.3 GHz.The RF Multiplexer can be configured for several arrangements, such as standard, tree, or matrix (see Chapter 4 for more information).

For a Standard Commands for Programmable Instruments (SCPI) environment, one or more RF Multiplexers (with or without Expanders connected) can be defined as a *switchbox* instrument. For a switchbox instrument, all RF Multiplexer channels within the instrument can be addressed using a single interface address.

Instrument Definition

Plug-in modules installed in a mainframe or used with a command module are treated as independent instruments each having a unique secondary GPIB address. Each instrument is also assigned a dedicated error queue, input and output buffers, status registers and, if applicable, dedicated mainframe/command module memory space for readings or data. An instrument may be composed of a single plug-in module (such as a counter) or multiple plug-in modules (for a Switchbox or Scanning Voltmeter Instrument).

Programming the RF Multiplexers

To program the RF Multiplexers using SCPI, you must select the controller language, interface address, and SCPI commands to be used. Guidelines to select SCPI commands for the RF Multiplexers follow. See the specific command module manual for interface addressing and controller language information.

NOTE *This discussion applies to SCPI programming. See Appendix B for details on programming RF Multiplexer registers.*

Addressing the Multiplexers

To address specific channels within an RF Multiplexer, you must specify the SCPI command and RF Multiplexer channel address. For the RF Multiplexer, use CLOSe (*channel_list*) to switch (connect) channels.

RF Multiplexer Channel Addresses

For the RF Multiplexer, the channel address (*channel_list*) has the form (@*ccmmnn*) where *cc* = RF Multiplexer card number (01-99), *mm* = RF Multiplexer/Expander module number (00-02), and *nn* = channel number (00-03, 10-13, 20-23, 30-33, 40-43, or 50-53). Use the form:

- (@*ccmmnn*) for a single channel
- (@*ccmmnn*,*ccmmnn*) for multiple channels

RF Multiplexer Card Numbers

The RF Multiplexer card number depends on the switchbox configuration (single-module or multiple-module) set for the RF Multiplexers. (Leading zeroes can be ignored for the card number.)

NOTE *The Expander module(s) card number is the same as the RF Multiplexer to which it is connected.*

- **Single-module**. For a single-module switchbox, the card number is always 01.
- **Multiple-module.** For a multiple-module switchbox, the RF Multiplexer module with the lowest logical address is always card number 01. The card number with the next successive logical address is 02, etc.

Figure 1-2 illustrates the card numbers and logical addresses of a typical multiple-module switchbox. The logical addresses in Figure 1-2 apply to RF Multiplexers installed in a VXI mainframe with a command module. See your specific command module manual for more information on switchboxes and logical addressing. For uses in other systems or mainframes, see the appropriate manuals.

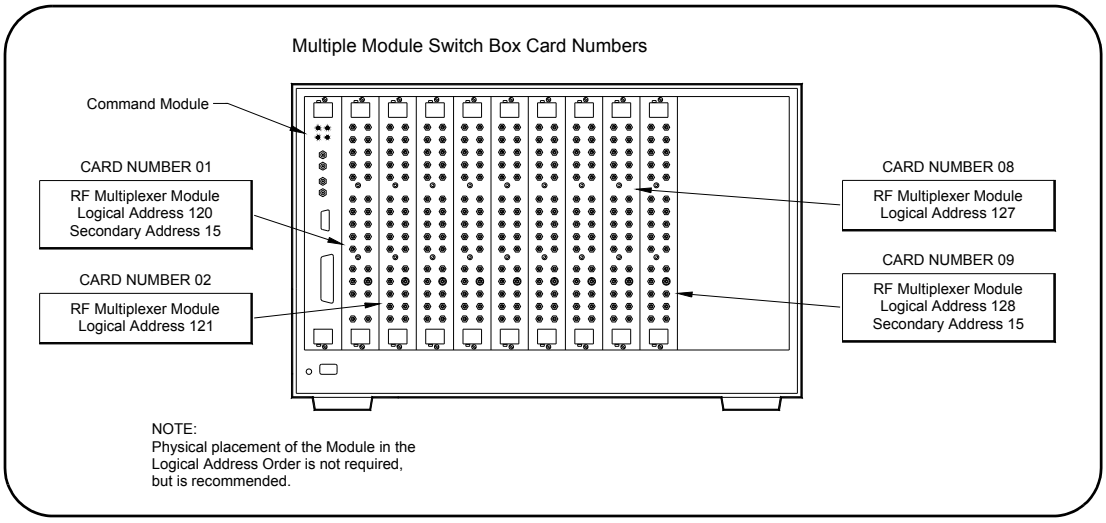

Figure 1-2. Card Numbers for Multiple-Module Switches

Module Numbers

The module number identifies the module (RF Multiplexer, Expander #1, or Expander #2) within the card. The number depends on the desired module (RF Multiplexer, Expander #1, or Expander #2). Figure 1-3 illustrates the module numbers of a typical card.

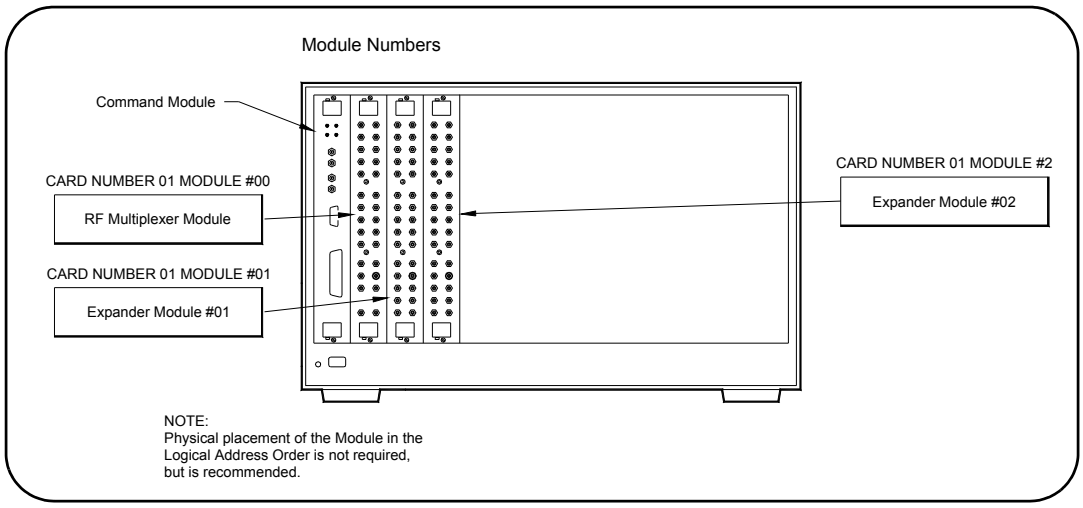

Figure 1-3. Typical Module Numbers

- **RF Multiplexer.** Module number is 00. If the RF Multiplexer does not have Expander module(s) connected, the module number can be omitted.
- **Expander module #1.** Module number is 01. Used to select the Expander module (if installed) connected to the RF Multiplexer RMD 3/RMD 2 internal ribbon connector.
- **Expander module #2.** Module number is 02. Used to select the Expander module (if installed) connected to the RF Multiplexer RMD 5/RMD 4 internal ribbon connector.

Channel Numbers

The channel numbers are 00-03, 10-13, 20-23, 30-33, 40-43, and 50-53. The channel is addressed using channel numbers. Use commas (,) to form a channel list. Only valid channels can be accessed in a channel list.

NOTE *The RF Multiplexer will accept and execute channel ranges (ccmmnn:ccmmnn) without generating an error, but the result is to close the last channel in each bank within the range specified. For example, after CLOSe (@010101:010151) is executed, card 01, module 01 channels 03, 13, 23, 33, 43, and 51 would remain closed.*

Example: RF Multiplexer Channel List

Channel Lists:

CLOSe (@10001)	*Connect channel 01 to COM 00 on the RF Multiplexer module, card 01.*
CLOSe (@10101,20101)	*Connect channel 01 to COM 00 on the Expander #1 module, cards 01 and 02.*

SCPI Command Format

You can send SCPI commands in either short or long form. A long form example is:

CLOSe (@10102)

The same command shown without the lower case letters is the short form. The command then becomes:

CLOS (@10102)

Some commands are shown with brackets ([ ]). These are implied or optional commands you do not have to execute. For example, the ROUTe command is an implied command and is shown as:

[ROUT:]CLOS (@10102)

Thus, to execute these commands, enter:

CLOS (@10102)

See Chapter 3 for more information about SCPI commands and how to send them.

Initial Operation

You can use the following program example to verify initial RF Multiplexer operation by closing a channel and querying channel closure. The example first resets the switchbox and then closes channel 02 of a single RF Multiplexer module (card number 1) in the switchbox.

The program next queries the channel closure state. A returned “1” shows that the command to close the channel has been sent to the switchbox. A returned “0" shows that the command to close the channel has not been sent to the switchbox.

This example uses BASIC as the program language. The computer interfaces to the mainframe using GPIB. The GPIB interface select code is 7, the primary address is 09, and the secondary address is 15. See the specific command module user’s guide for addressing information.

```
10 OUTPUT 70915;"*RST"                  !Resets the module. Switches all channel n0 to COM n0.
20 OUTPUT 70915;"CLOS (@102)"           !Connect channel 02 to COM 00.
30 OUTPUT 70915;"CLOS? (@102)"          !Query channel 02.
40 ENTER 70915;Value                    !Enter results into value.
50 PRINT Value                          !Display results (should return "1").
60 END                                  !End program.
```

Chapter 2
Configuring the RF Multiplexers

Using This Chapter

This chapter shows how to connect external wiring to the RF Multiplexer and Expander connectors and how to configure the modules for operation.

- Warnings and Cautions 17
- Setting the Address Switch 18
- Selecting the Interrupt Priority 19
- Expanding the RF Multiplexer 20
- Selecting the Relay Drive Level 22
- Connecting User Inputs to E1472A/73A 24
- Connecting User Inputs to E1474A/75A 25
- Cables and Connectors 28

Warnings and Cautions

WARNING

SHOCK HAZARD. Only service-trained personnel who are aware of the hazards involved should install, remove, or configure the RF Multiplexer. Before you remove any installed module, disconnect AC power from the mainframe and from other modules that may be connected to the RF Multiplexer.

CHANNEL WIRING INSULATION. All channels that have a common connection must be insulated so that the user is protected from electrical shock in the event that two or more channels are connected together. This means wiring for all channels must be insulated as though each channel carries the voltage of the highest voltage channel.

CAUTION

MAXIMUM POWER. The maximum power that can be applied to any SMB connector is 24 W (24 VA). The maximum voltage that can be applied to any SMB connector is 42V peak. The maximum current that can be applied to any SMB connector is 1A DC/AC RMS.

STATIC ELECTRICITY. Static electricity is a major cause of component failure. To prevent damage to the electrical components in the RF Multiplexer, observe anti-static techniques whenever removing a module from the mainframe or whenever working on a module.

Setting the Address Switch

The logical address switch (LADDR) factory setting is 120. You may have changed the setting during module installation. Valid address values are from 0 to 255. If the RF Multiplexer is used with a command module in a C-Size mainframe, see the command module user's guide for addressing information. Otherwise, see Figure 2-1 to change the setting.

NOTE *The address switch selected value must be a multiple of 8 if the module is the first module in a "switchbox" used in a VXI mainframe, and is being instructed by SCPI commands.*

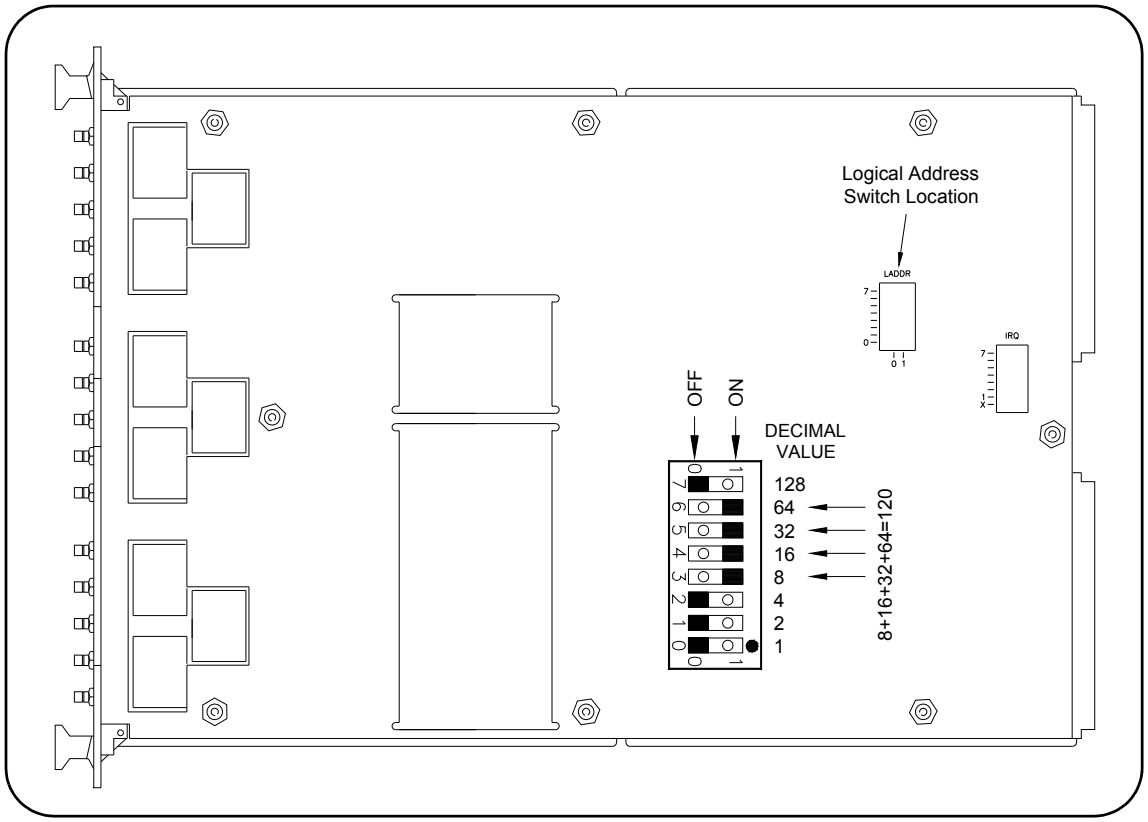

Figure 2-1. Address Selection

Selecting the Interrupt Priority

The RF Multiplexer module generates an interrupt after a channel has been closed. These interrupts are sent to, and acknowledgements are received from, the command module via the VXIbus backplane interrupt lines.

For most applications where the RF Multiplexer module is installed in a C-Size mainframe, the interrupt priority jumper does not have to be moved. This is because the VXIbus interrupt lines have the same priority and interrupt priority is established by installing modules in slots numerically closest to the command module. Thus, slot 1 has a higher priority than slot 2, slot 2 has a higher priority than slot 3, etc.

See Figure 2-2 to change the interrupt priority. You can select eight different interrupt priority levels. Level 1 is the lowest priority and Level 7 is the highest priority. Level X disables the interrupt. The module's factory setting is Level 1. To change, remove the 4-pin jumper (part number 1258-0247) from the old priority location and reinstall in the new priority location (Figure 2-2 shows a priority change from 1 to 7). If the 4-pin jumper is not used, the two jumper locations must have the same interrupt priority level selected (see Figure 2-2).

NOTE *Level X interrupt priority should not be used under normal operating conditions. Changing the priority level jumper is not recommended. Do not change unless specifically instructed to do so.*

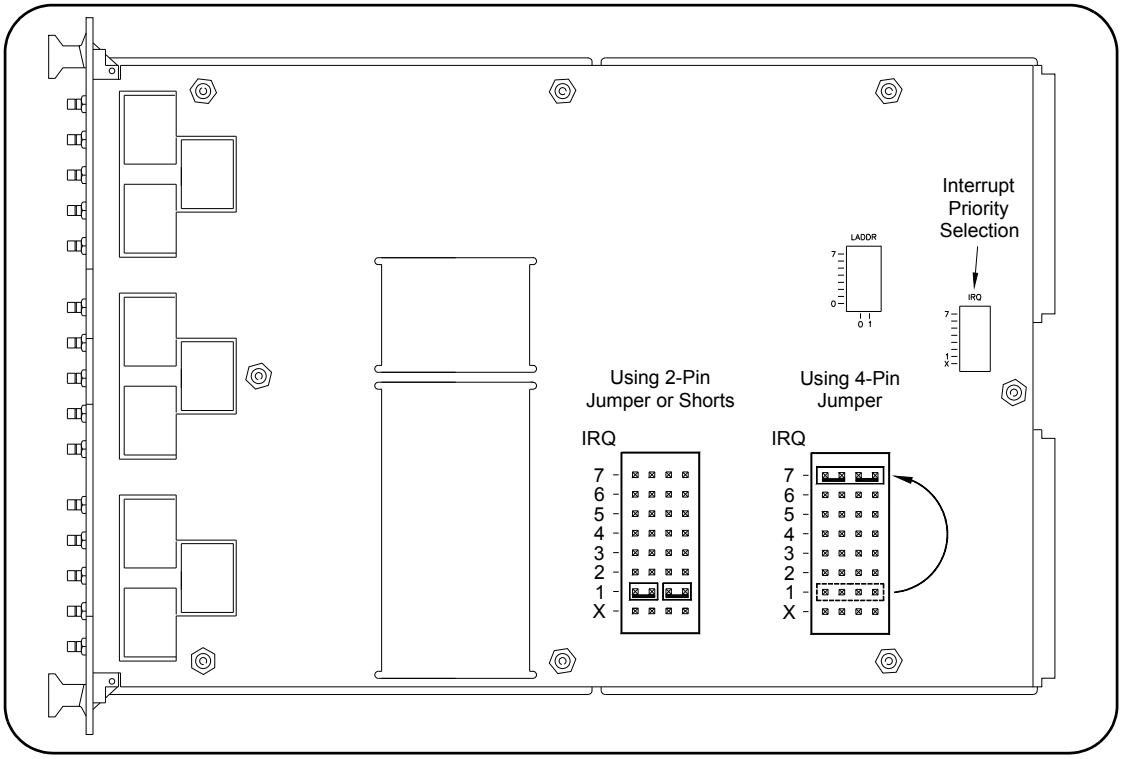

Figure 2-2. Interrupt Priority Selection

Expanding the RF Multiplexer

Each RF Multiplexer module is capable of controlling up to two Expander modules, providing a total of eighteen (4:1) banks. The Expander modules can be physically located in the C-Size mainframe next to the RF Multiplexer, or up to eight meters away using extension cables. Use Figure 2-3 and the following procedure to connect the Expander modules.

1 Verify a 3-1 cable (part number E1472-61601) is installed in the Remote Module Driver (RMD) 2/4/5 cable slot. Cable can be connected without removing the shield.

2 Cut the cable ties holding the cables, and pull the cables through the slots in the shield.

3 Mark the 3-1 cables as shown in Figure 2-3 (cross out unused RMD number).

4 Connect the 3-1 cables to the Expander modules as follows:
- RMD3 cable to Expander (module 01) Bank 3-5 connector.
- RMD2 cable to Expander (module 01) Bank 0-2 connector.
- RMD5 cable to Expander (module 02) Bank 3-5 connector.
- RMD4 cable to Expander (module 02) Bank 0-2 connector.

NOTE *RMD1 cable is connected to E1472A/74A (module 00) Bank 3-5 connector, and RMD0 cable is connected to E1472/74A (module 00) Bank 0-2 connector at the factory. These connections are not accessible with the shield in place and should not be moved.*

5 If the Expander module is physically located (up to eight meters) away from the mainframe, you can daisy chain up to 10 extender cables (part number E1473-80002) for each RMD connection (see Figure 2-3, module 02).

6 Fold and tie unused RMD cables.

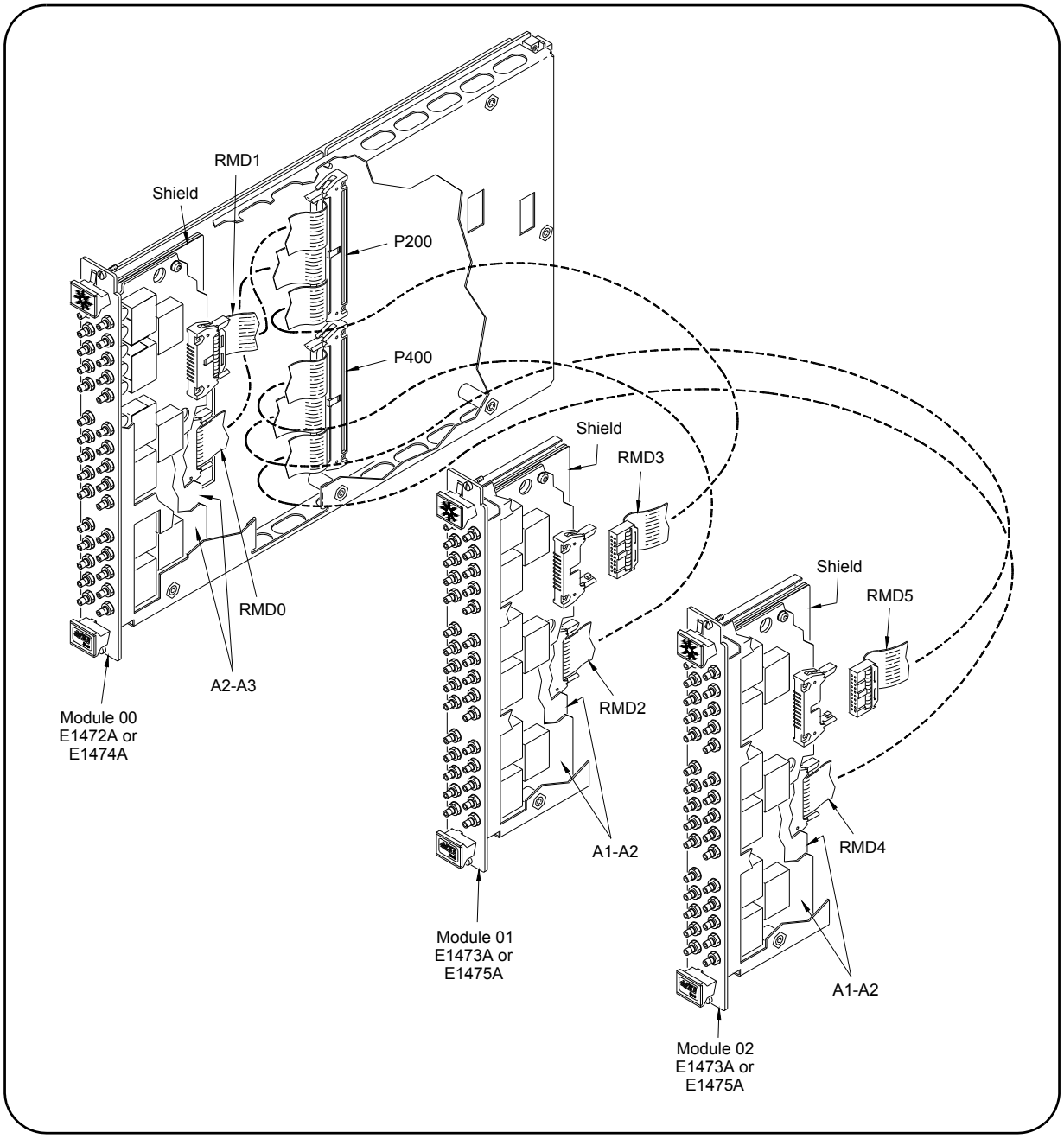

Figure 2-3. Expander Module Connections

Selecting the Relay Drive Level

The relay drive level is set at the factory to +12 Vdc. This is the level used by both the RF Multiplexer module and the Expander module relays.

NOTE *DO NOT CHANGE the relay drive level if using E1472A, E1473A, E1474A, or E1475A modules.*

If external relays of +5 Vdc or +24 Vdc are used with the RF Multiplexer module, the drive level must be changed as follows:

1 Position the RF Multiplexer on a flat surface.

2 Using a TORX T-10 driver, remove the eight screws (part number 0515-1135).

3 From the rear, carefully lift shield enough to access jumpers.

CAUTION **POSSIBLE RELAY DAMAGE.** Relays may be permanently damaged if the incorrect relay drive level is selected. Change the relay drive level only when ALL relays used (modules 00 AND 01 AND 02) require a +5V or +24V drive level.

CAUTION **POSSIBLE SHIELD DAMAGE.** The shield is connected to the front panel and will be damaged if bent too far. Do not move the RF Multiplexer module from the flat surface with the shield in this condition. It may be necessary to loosen the SMB connector nuts to access the jumpers.

4 Move both jumpers (part number 1258-0141) from the +12 Vdc position to the desired drive level. Jumper J200 sets the voltage drive level for the relay modules connected to P200. Jumper J400 sets the voltage drive level for the relay modules connected to P400.

5 Reinstall the eight screws.

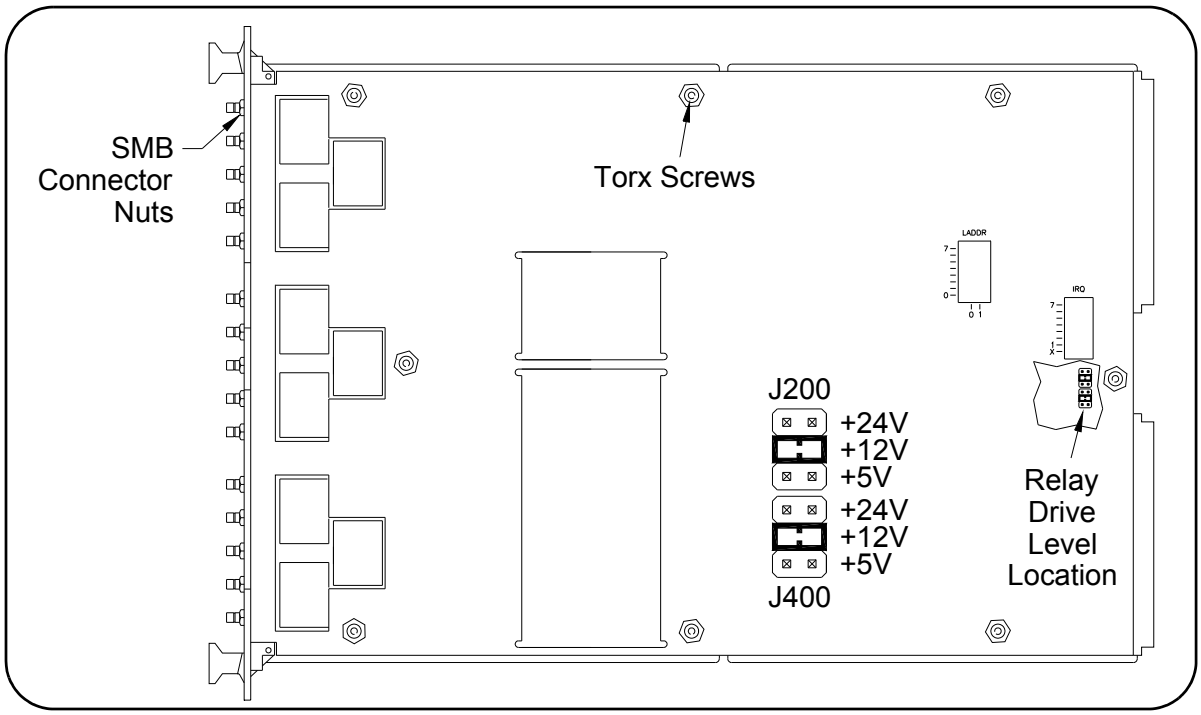

Figure 2-4. Relay Drive Level Selection

Connecting User Inputs to E1472A/E1473A

User inputs to the E1472A RF Multiplexer and E1473A Expander modules are via user-supplied female 50 Ohm SMB connectors to the male 50 Ohm SMB connectors on the modules. Figure 2-5 shows the RF Multiplexer 50 Ohm SMB connectors and associated channel numbers.

Cabling Guidelines

- For best high-frequency performance, user cabling should have at least two braided shields or one braid and a foil wrap.
- Always use shielded coaxial cables with the characteristic impedance of 50 Ohms. Keep cables as short as possible, especially in high-frequency circuits or pulse circuits where a rise/fall time is critical.
- Long cables can add delay time which can cause timing problems. All test equipment, such as counters, spectrum analyzers, and oscilloscopes must be terminated in the characteristic impedance (50 Ohms) to minimize reflection loss.

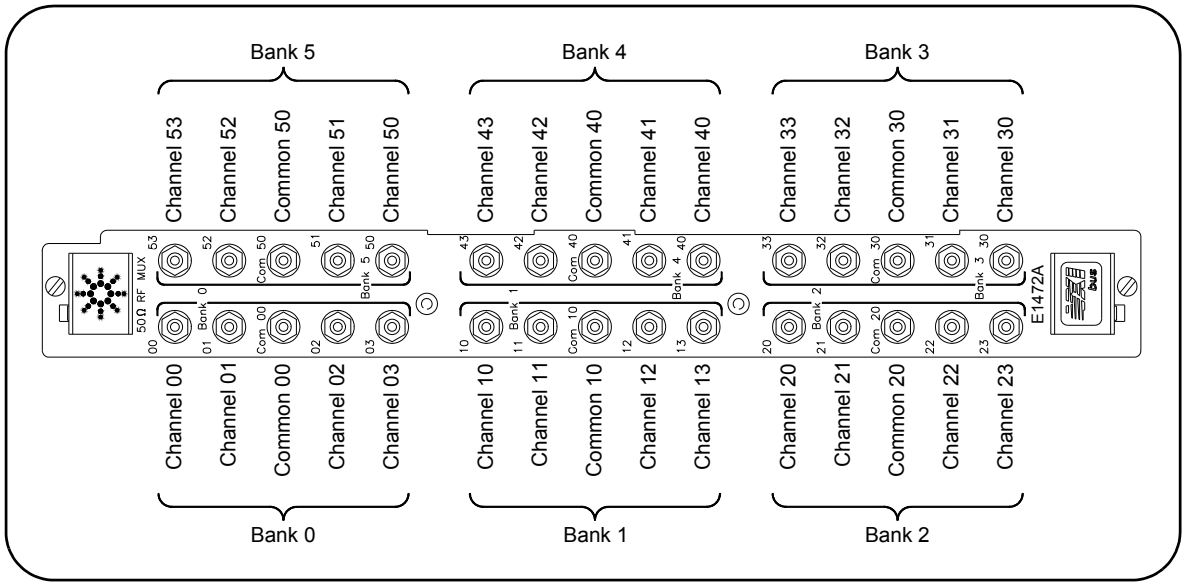

Figure 2-5. 50 Ohm SMB Connector Locations

Connecting User Inputs to E1474A/E1475A

User inputs to the RF Multiplexer and Expander modules are via user-supplied female 75 Ohm SMB connectors to the male 75 Ohm SMB connectors on the modules. Figure 2-6 shows the RF Multiplexer 75 Ohm SMB connectors and associated channel numbers.

Cabling Guidelines

- The 75 Ohm connectors only work with one braided shield or one braid and a foil wrap.
- Always use shielded coaxial cables with the characteristic impedance of 75 Ohm. Keep cables as short as possible, especially in high-frequency circuits or pulse circuits where a rise/fall time is critical.
- Long cables can add delay time which can cause timing problems. All test equipment, such as counters, spectrum analyzers, and oscilloscopes must be terminated in the characteristic impedance (75 Ohm) to minimize reflection loss.
- The 75 Ohm SMB connectors are significantly different than the standard 50 Ohm SMB connectors. Carefully plug the connectors in and out to minimize damage to the connector. The 75 Ohm SMB mating connectors and accessories are available only from Agilent or E.F. Johnson Co.[1]
- See Examples 1 and 2 for information on connectors and accessories.

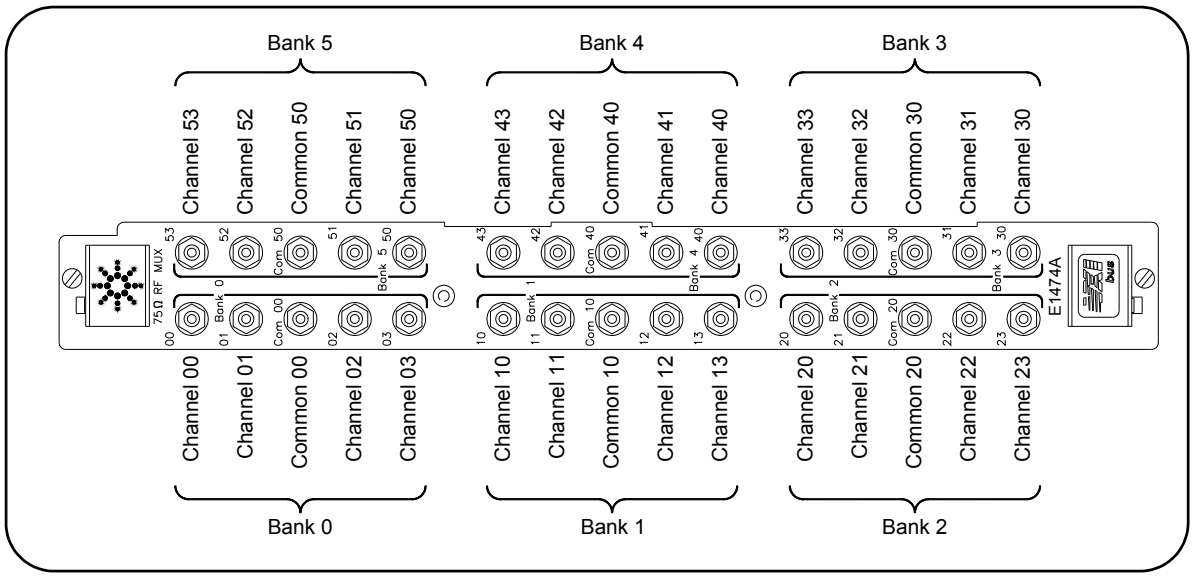

Figure 2-6. 75 Ohm SMB Connector Locations

1. E.F. Johnson Co., 299 Johnson Ave., Waseca, MN 56093-0514. Telephone: 1-800-247-8256, FAX: 1-507-835-6287

Example 1: Connection to a Network Analyzer

Figure 2-7 shows how to connect the E1474A/E1475A RF multiplexer to an 8753 Network Analyzer with an 85046B 75 Ohm S-Parameter test set. Similar connections can be used for other devices. The Type N plug is available from Trompeter Electronics[1] (part number UPL 95-5). The cable used is RG179.

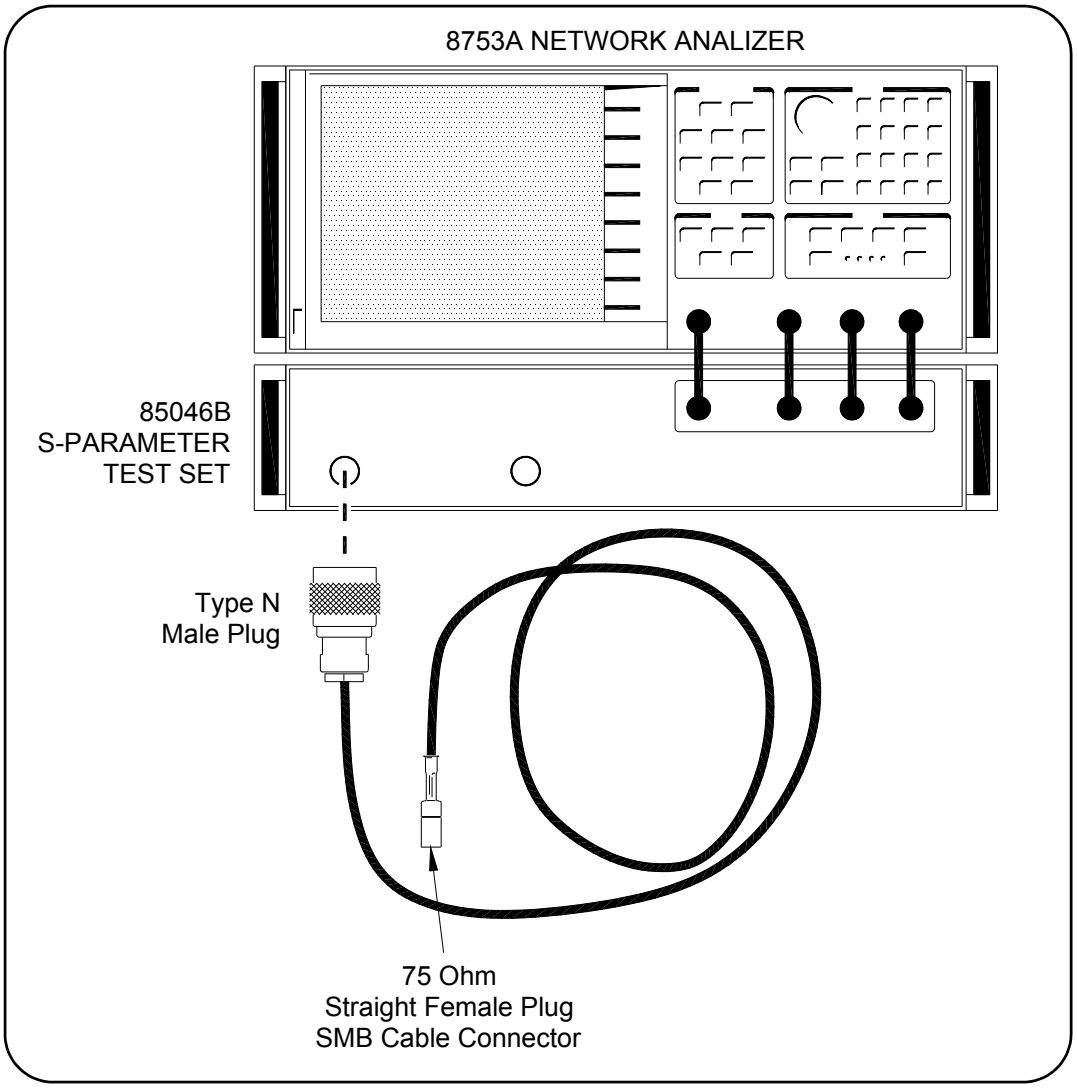

Figure 2-7. Connection to Network Analyzer with 75 Ohm S-Parameter Test Set

1. Trompter Electronics, 31186 La Baya Drive, Westlake Village, CA. 91362-4047. Telephone (818) 707-2020

Example 2: Connection to a Network Analyzer

Figure 2-8 shows how to connect the E1474A/E1475A RF multiplexer to an 8753 Network Analyzer with an 85046A 50 Ohm S-Parameter test set. Similar connections can be used for other devices.

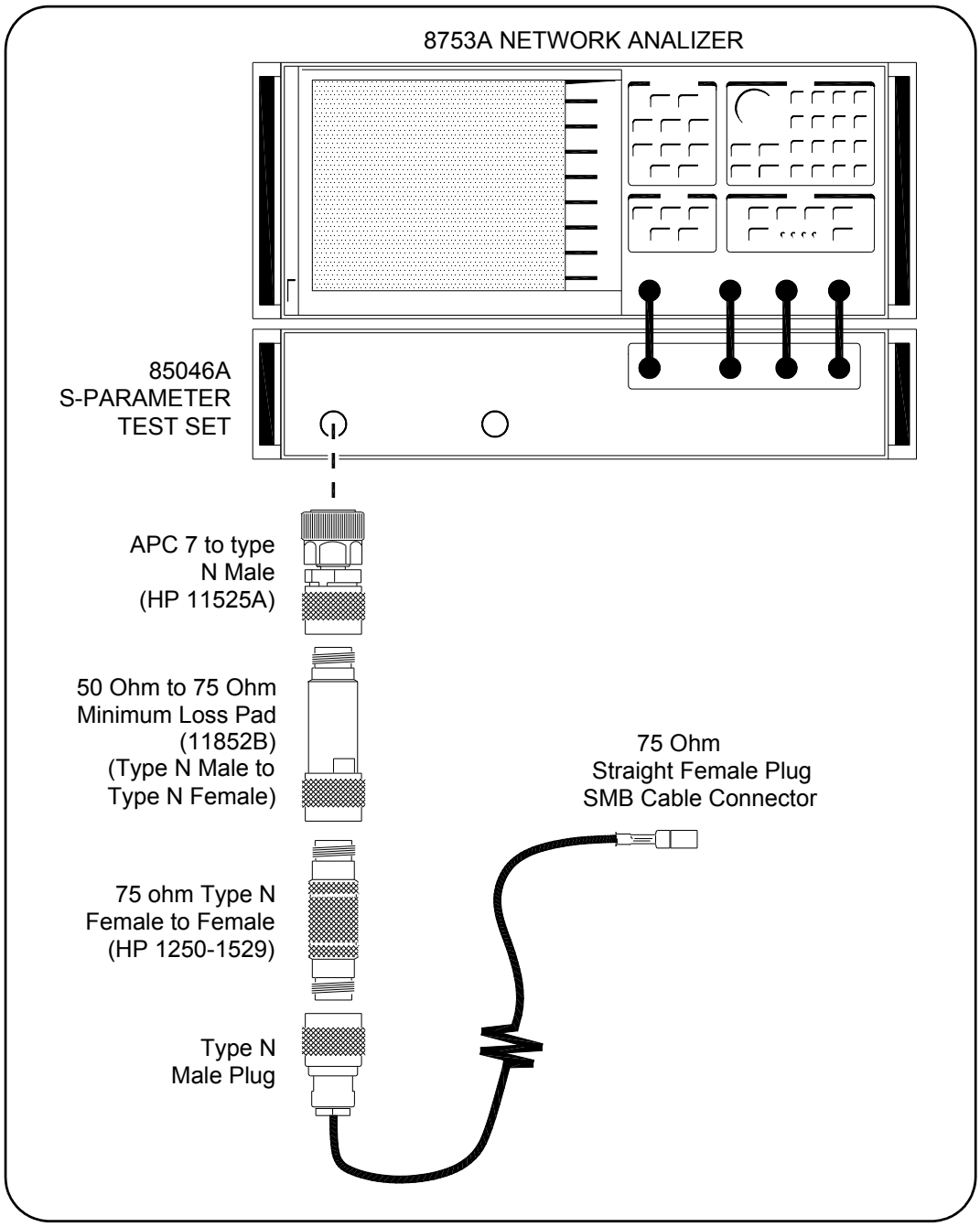

Figure 2-8. Connection to Network Analyzer with 50 Ohm S-Parameter Test Set

Cables and Connectors

Cables

The following tables list 50 Ohm and 75 Ohm cables and connectors available from Agilent. Some 75 Ohm connectors are also available from E.F. Johnson Company.

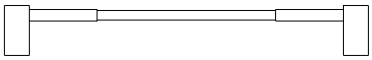

Table 2-1. Right-Angle SMB Female (Plug) to Right-Angle SMB Female (Plug)

Length	50 Ohm Part Number	75 Ohm Part Number
55mm (2")	8120-5627	8120-5589
75mm (3")	8120-5628	8120-5590
125mm (5")	8120-5629	8120-5591
175mm (7")	8120-5630	8120-5592
330mm (13")	8120-5631	8120-5593
430mm (17")	8120-5632	8120-5594
925mm (36")	8120-5633	8120-5595

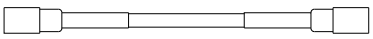

Table 2-2. Straight SMB Female (Plug) to Straight SMB Female (Plug)

Length	50 Ohm Part Number	75 Ohm Part Number
125mm (5")	8120-5091	8120-5584
175mm (7")	8120-5623	8120-5585
330mm (13")	8120-5624	8120-5586
430mm (17")	8120-5625	8120-5587
925mm (36")	8120-5626	8120-5588

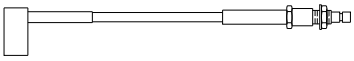

Table 2-3. Right-Angle SMB Female (Plug) to Bulkhead SMB Male (Jack)

Length	50 Ohm Part Number	75 Ohm Part Number
125mm (5")	8120-5608	8120-5579
175mm (7")	8120-5609	8120-5580
330mm (13")	8120-5610	8120-5581
430mm (17")	8120-5611	8120-5582
925mm (36")	8120-5612	8120-5583

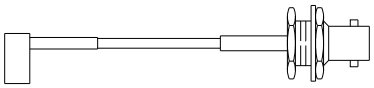

Table 2-4. Right-Angle SMB Female (Plug) to Bulkhead BNC Male (Plug)

Length	50 Ohm Part Number	75 Ohm Part Number
125mm (5")	8120-5603	8120-5598
175mm (7")	8120-5604	8120-5599
330mm (13")	8120-5605	8120-5600
430mm (17")	8120-5606	8120-5601
925mm (36")	8120-5607	8120-5602

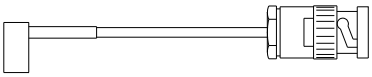

Table 2-5. Right-Angle SMB Female (Plug) to Bulkhead-mount BNC Female (Jack)[a]

Length	50 Ohm Part Number	75 Ohm Part Number
125mm (5")	8120-5613	8120-5618
175mm (7")	8120-5614	8120-5619
325mm (13")	8120-5615	8120-5620
425mm (17")	8120-5616	8120-5621
925mm (36")	8120-5617	8120-5622
a. SMB jacks are “male”, SMB plugs are “female”, BNC jacks are “female”, and BNC plugs are “male”.		

Connectors

Tables 2-6 and 2-7 list available 75 Ohm and 50 Ohm SMB connectors. See Figure 2-9 for a diagram of each connector.

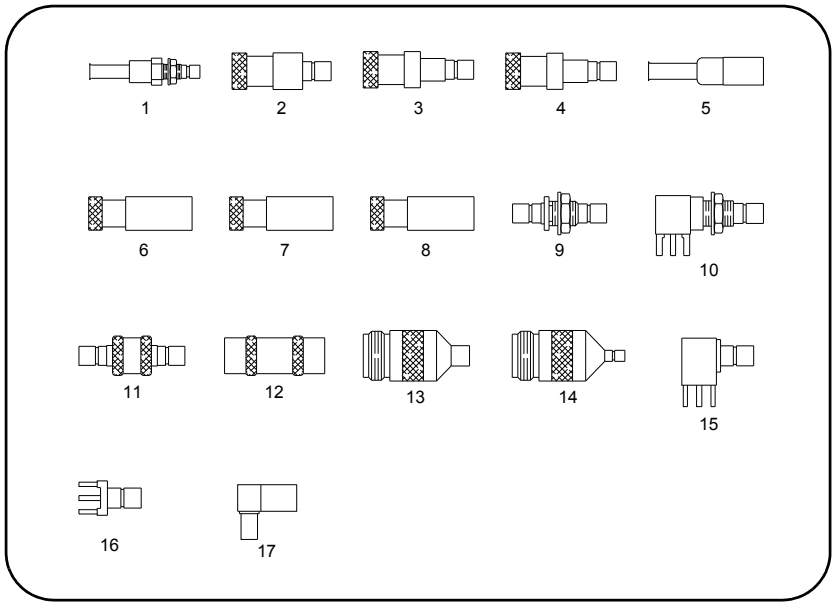

Figure 2-9. SMB Connector Drawings

Table 2-6. 75 Ohm SMB Connectors

Dwg Nbr	Description	Agilent P. N.	Johnson P. N.
1	Jack (male) Straight Bulkhead SMB Cable Connector	1250-2341	131-8303-401
2	Jack (male) Load	1250-2342	131-8701-801
3	Jack (male) Short	1250-2358	131-8701-811
4	Jack (male) Open	1250-2354	131-8701-821
5	Plug (female) Straight SMB Cable Connector	1250-2336	131-8403-001
6	Plug (female) 75 Ohm Load	1250-2343	131-8801-801
7	Plug (female) Short	1250-2359	131-8801-311
8	Plug (female) Open	1250-2355	131-8801-821
9	In-series Adapter Jack - Bulkhead Jack	1250-2337	131-8901-401
10	Right-Angle Bulkhead Jack	1250-2356	131-8701-501
11	Male Jack to Male Jack	1250-2378	131-8901-801
12	Female plug to Female Plug	1250-2377	131-8901-811
13	75 Ohm Type N Jack to 75 Ohm SMB Female Plug	N/A	134-1069-021
14	75 Ohm Type N Jack to 75 Ohm SMB Male Jack	N/A	134-1069-031
15	Right Angle Jack Receptacle	1250-2339	131-8701-301
16	Straight Jack Receptacle	1250-2335	131-8701-201
17	Right Angle Crimp Type Plug	1250-2340	131-8403-101

Table 2-7. 50 Ohm SMB Connectors

Dwg No.	Description	Part Number
1	Jack (male) Straight Bulkhead SMB Cable Connector	1250-1902
5	Plug (female) Straight SMB Cable Connector	1250-1907
6	Plug (female) 50 Ohm Load	1250-0676
7	Plug (female) Short	1250-0911
9	In-series Adapter Jack - Bulkhead Jack	1250-1593
11	Male Jack to Male Jack	1250-0669
12	Female plug to Female plug	1250-0672
15	Right Angle Jack Receptacle	1250-0543
16	Straight Jack Receptacle	1250-0257
17	Right Angle Crimp Type Plug	1250-1901

Chapter 3
Using the RF Multiplexers

Using This Chapter

This chapter uses typical examples to show how to use the RF Multiplexer and Expander modules. This chapter contains the following sections:

- RF Multiplexer Commands 31
- Switching Channels 32
- Saving and Recalling States 34
- Detecting Error Conditions 34
- Synchronizing the RF Multiplexer 36

RF Multiplexer Commands

Table 3-1. RF Multiplexer Commands Used in Chapter 3

Command	Description
[ROUT:]CLOS *<channel_list>*	Close the channels in the <*channel_list*>
[ROUT:]CLOS? *<channel_list>*	Queries the state of the channels in the <*channel_list*>
[ROUT:]OPEN? *<channel_list>*	Queries the state of the channels in the <*channel_list*>
*CLS	Clears all switchbox status register.
*ESE	Enables event status register
*RST	Sets the hardware and software to a known state
*SRE	Enables status register

NOTE *When the RF Multiplexer is switched off, switched on, or *RST (reset), all banks close channel n0 to COMmon. When the RF Multiplexer is powered up or down, signals connected to the channel n0 connector will also be connected to the COMmon connector.*

Switching Channels

For general purpose switch operation, you can connect a signal by closing a specific channel to its COMmon. One channel per bank will be connected to COMmon at all times, and only one channel per bank can be closed at a time. Switching configurations include standard, matrix, and tree. The following channel configurations are possible.

- Close channels 00 to 03 by connecting a channel to COM00.
- Close channels 10 to 13 by connecting a channel to COM10.
- Close channels 20 to 23 by connecting a channel to COM20.
- Close channels 30 to 33 by connecting a channel to COM30.
- Close channels 40 to 43 by connecting a channel to COM40.
- Close channels 50 to 53 by connecting a channel to COM50.

Use CLOSe *channel_list* to close a channel to COMmon. *channel_list* has the form (@*ccmmnn*) for a single channel, and (@*ccmmnn*,*ccmmnn*,...) for two or more channels.

- *cc* = card number (01-99).
- *mm* = module number (00-02).
- *nn* = channel number (00-03, 10-13, 20-23, 30-33, 40-43, 50-53).

NOTE *The following examples are shown using multiple configurations (multiple-module switchbox and single module switchbox with Expander modules) to illustrate programming differences. All the examples shown could have been performed using only one E1472A or E1474A RF Multiplexer module.*

Example: Standard Switching

You can use standard switching to switch channels n0-n3 to COM n0 (where n = Switching bank number 0 to 5). One channel per bank can be connected to its common at a time.This example connects channel 11 to COM10 of an RF Multiplexer in a standard configuration. The RF Multiplexer without Expander modules is defined as a single-multiplexer switchbox instrument. In Figure 3-1, execute CLOS (@111) to connect COM 10 to channel 11 .

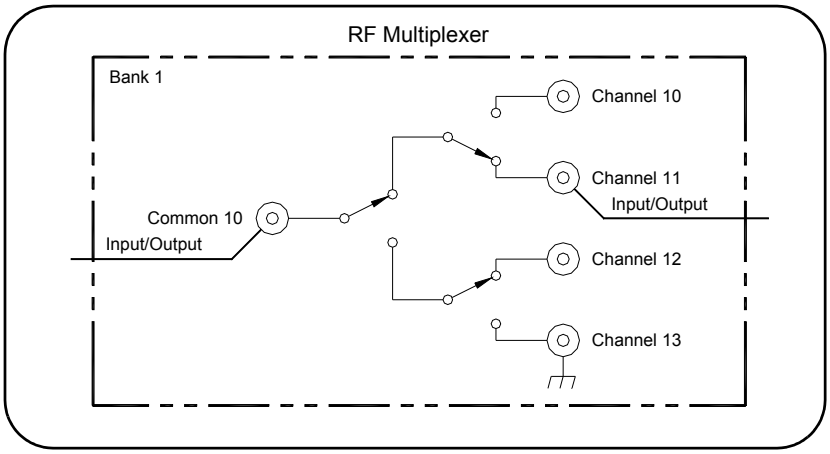

Figure 3-1. Example: RF Multiplexer Standard Switching

Example: Tree Switching

Use tree switching to provide signal routing while maintaining characteristic impedance. With tree switching, signal delay time is more than doubled since the signal must pass through two or more channel banks plus extra cabling. Keep cables as short as possible, especially between channel banks, to minimize delay.

This example uses two RF Multiplexers in a tree configuration to connect COM 10 of RF Multiplexer number 01 to channel 13 of RF Multiplexer 02. The two RF Multiplexers form a multiple-multiplexer switchbox instrument. In Figure 3-2,execute CLOS (@111,213) to connect COM 10 to channel 13.

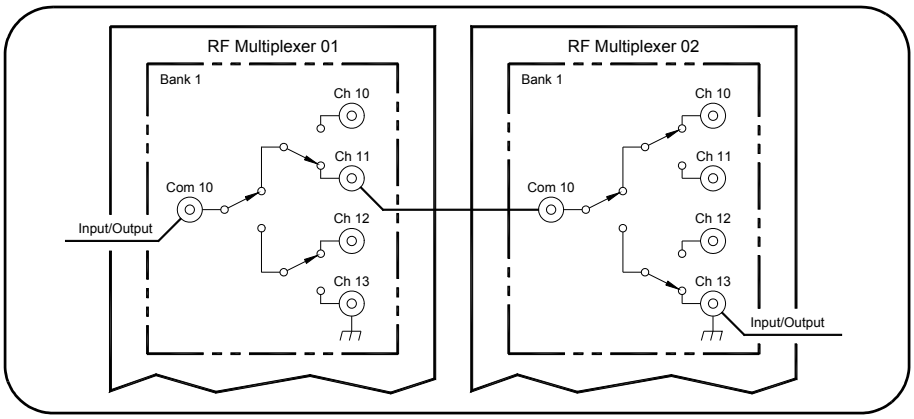

Figure 3-2. Example: RF Multiplexer Tree Switching

Example: Matrix-Type Switching

You can use matrix-type switching to provide connection of up to four devices under test (DUT) to up to four test instruments. With this configuration, only one channel in bank 0 (one “row”) can be connected to one channel in bank 1 (one “column”) at a time.

This example uses one RF Multiplexer and one Expander in a matrix-type configuration to connect channel 03 of the RF Multiplexer (module 00) to channel 11 of the Expander (module 01). The RF Multiplexer and Expander modules are defined as a single-multiplexer switchbox instrument. In Figure 3-3, execute CLOS (@10003,10111) to connect channel 03 to channel 11.

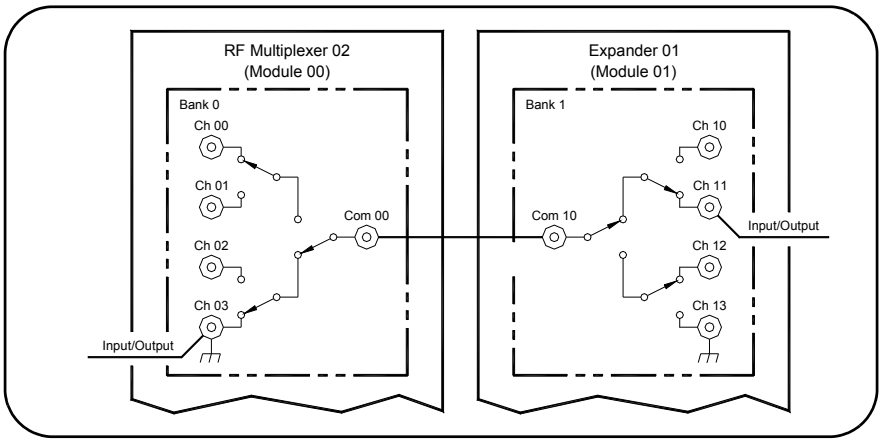

Figure 3-3. Example: Multiplexer/Expander Matrix Type Switching

Saving and Recalling States

The *SAV <*numeric_state*> command saves the current instrument state. The state number (0-9) is specified in the <*numeric_state*> parameter. The channel states (channel closed to common) are saved.

The *RCL <*numeric_state*> command recalls a previously saved state. Enter the number (0-9) in the <*numeric_state*> parameter of the desired saved state. If *SAV was not previously executed using the selected number, the RF Multiplexer will configure to the reset values (channel 0 to COMmon on all banks).

Detecting Error Conditions

There are two general approaches to error checking. The simplest, but most time consuming, is to ask the instrument whether there are errors at every step of the switching process. This is called “polling” and is illustrated in the following example.

Example: Polling Method of Error Checking

```
05   DIM Err_num$ [256]
10    OUTPUT 70915; "CLOS(@101);:SYST:ERR?"
20    ENTER 70915;Err_num$
30    IF VAL (Err_num$) <> 0 THEN
40        PRINT "Error";Err_num$
50        STOP
60    END IF
70   . . . (program continues)
```

Example: Error Checking Using Interrupts

The other approach involves the use of interrupts. The following program is a method of checking for errors using interrupts as you program the RF Multiplexer. The program monitors the RF Multiplexer’s Standard Event Status Register for an error condition.

If no errors occur, the RF Multiplexer functions as programmed. If errors do occur, the RF Multiplexer interrupts the computer, and the error codes and messages are read from the error queue. This approach requires less checking but is more complex. This BASIC example uses a GPIB select code of 7, primary address of 09, and secondary address of 15 for the RF Multiplexer.

```
10  !Call computer subprogram "Errmsg" if an RF Multiplexer programming
20  !error occurs. Enable the computer to respond to an interrupt from the
30  !RF Multiplexer.
35  !
40  ON INTR 7 CALL Errmsg
50  ENABLE INTR 7:2
```

```
60  !
70  !Unmask the Event Status bit in the RF Multiplexer's Status
80  !Register. Unmask the RF Multiplexer error conditions in its
90  !Standard Event Status Register.
100  OUTPUT 70915;"*SRE 32"
110  OUTPUT 70915;"*ESE 64"
120  !
130  !At this point, the RF Multiplexer is programmed for the
140  !intended application.
145  !
150  OUTPUT 70915;" . . .
160  OUTPUT 70915;" . . .
170  ENTER 70915; . . .
180  PRINT . . .
190  END
200  !
210  !When an error occurs, clear the RF Multiplexer to regain
220  !control. Execute a Serial Poll to clear the service request
230  !bit in the Status Register. Read all error messages in the
240  !RF Multiplexer error queue. Clear all bits in the RF Multiplexer
250  !Standard Event Status Register.
255  !
260  SUB Errmsg
270    DIM Message$[256]
280    CLEAR 70915
290    B=SPOLL (70915)
300    REPEAT
310      OUTPUT 70915; "SYST:ERR?"
320      ENTER 70915; Code, Message$
330      PRINT Code,Message$
340    UNTIL Code=0
350    OUTPUT 70915;"*CLS"
360    STOP
370  SUBEND
```

Synchronizing the RF Multiplexer

This section discusses synchronizing the RF Multiplexer module to other instruments when making measurements. In the following example the RF Multiplexer switches a signal to be measured by a counter. This program verifies that switching is complete before the counter begins a measurement.

This example uses a GPIB select code of 7, primary address of 09, and secondary address of 06 for the Counter and a GPIB select code of 7, primary address of 09, and secondary address of 15 for the RF Multiplexer.

```
10  ! Close channel 01 and request confirmation the channel is closed.
20  OUTPUT 70915;"CLOSE (@101);*OPC?"
25  ENTER 70915;OPC_value
30  !Read confirmation.
35  OUTPUT 70915;"CLOSE? (@101)"
40  ENTER 70915;A
50  !At this point (channel is closed) the measurement can be made.
60  OUTPUT 70906: "MEAS:FREQ?"
70  ENTER 70906:Meas_value
80  END
```

Chapter 4
RF Multiplexer Command Reference

Using This Chapter

This chapter describes Standard Commands for Programmable Instruments (SCPI) commands and summarizes IEEE 488.2 Common (*) commands applicable to the RF Multiplexer. See the *Agilent Command Module User's Guide* for additional information on SCPI and common commands.

- Command Types 37
- SCPI Command Reference 39
- Common Commands Quick Reference 46
- SCPI Commands Quick Reference 47

Command Types

Commands are separated into two types: IEEE 488.2 Common Commands and SCPI Commands.

Common Command Format

The IEEE 488.2 standard defines the Common Commands that perform functions like reset, self-test, status byte query, etc. Common commands are four or five characters in length, always begin with the asterisk character (*), and may include one or more parameters. The command keyword is separated from the first parameter by a space character. Some examples of Common Commands are:

```
*RST    *ESR 32    *STB?
```

SCPI Command Format

The SCPI commands perform functions like closing switches, querying instrument states, or retrieving data. A subsystem command structure is a hierarchical structure that usually consists of a top level (or root) command, one or more lower level sub commands, and their parameters. The following example shows a typical subsystem:

```
[ROUTe:]
  CLOSe <channel_list>
```

[ROUTe:] is the root command, :CLOSe is the second level sub command, and <*channel_list*> is a parameter.

Command Separator

A colon (:) always separates one command from the next lower level command, such as ROUTe:CLOSe? Colons separate the root command from the second level (ROUTe:CLOSe?). If a third level exists, the second level is also separated from the third level by a colon.

Abbreviated Commands

The command syntax shows most commands as a mix of upper and lower case letters. The upper case letters indicate the abbreviated spelling for the command. For shorter program lines, send only the abbreviated form. For better program readability, you may send the entire command. The instrument will only accept either the abbreviated form or the entire command.

For example, if the command syntax shows CLOSe, CLOS and CLOSE are both acceptable forms. Other forms of CLOSe, such as CL or CLO will generate an error. You may use upper or lower case letters. Therefore, CLOSE, and ClOsE are both acceptable.

Implied Commands

Implied commands are those which appear in square brackets ([ ]) in the command syntax. (The brackets are not part of the command and are not sent to the instrument.) Suppose you send a second level command but do not send the preceding implied command. In this case, the instrument assumes you intend to use the implied command and it responds as if you had sent it. Examine the portion of the ROUTe subsystem shown below:

```
[ROUTe:]
   CLOSe? <channel_list>
```

The root command ROUTe: is an implied command. To make a query about a channel's present status, you can send either of the following command statements:

ROUT:CLOSe? <*channel_list*> or CLOSe? <*channel_list*>

Parameters

This table contains explanations and examples of parameter types that can be used.

Parameter Type	Explanations and Examples
Numeric	Accepts all commonly used decimal representations of numbers including optional signs, decimal points, and scientific notation, such as 123 or 1.23E2; -123 or -1.23E2; .123, 1.23E-1, or 1.23000E-01. Special cases include MIN, MAX, and DEF. MIN selects minimum value available, MAX selects maximum value available, and DEF selects default or reset value.
Boolean	Represents a single binary condition that is either true or false (1 or ON; 0 or OFF)
Discrete	Selects from a finite number of values. These parameters use mnemonics to represent each valid setting. An example is the TRIGger:SOURce <*source*> command where <*source*> can be BUS, HOLD, or IMMediate.

Linking Commands

Linking IEEE 488.2 Common Commands with SCPI Commands. Use a semicolon between the commands. For example:

*RST;*RCL 1 or CLOS (@101);*SAV 1

Linking Multiple SCPI Commands. Use both a semicolon and a colon between the commands. For example:

CLOS (@101);:CLOS? (@101)

SCPI also allows several commands within the same subsystem to be linked with a semicolon. For example:

ROUT:CLOS (@101);:ROUT:CLOS? (@101)

or

ROUT:CLOS (@101);CLOS? (@101)

SCPI Command Reference

This section describes Standard Commands for Programmable Instruments (SCPI) for the RF Multiplexer. Commands are listed alphabetically by subsystem and also within each subsystem.

[ROUTe:]

The ROUTe command subsystem controls switching operations for the RF Multiplexer in a switchbox.

Subsystem Syntax

[ROUTe:]
CLOSe <*channel_list*>
CLOSe? <*channel_list*>
OPEN? <*channel_list*>

[ROUTe:]CLOSe

ROUTe:]CLOSe <*channel_list* > closes the RF Multiplexer channels specified by *channel_list*. *channel_list* has the form (@*ccmmnn*) where *cc* = card number (01-99), *mm* = module number (00-02), and *nn* = channel number (00-03, 10-13, 20-23, 30-33, 40-43, or 50-53).

Parameters

Name	Type	Range	Item
<*channel_list*>	numeric numeric numeric	01-99 00-02 00-03 |10-13 |20-23 |30-33 |40-43 |50-53	card (*cc*) module (*mm*) channel (*nn*)

Comments

Closing Channels: To close a single channel, use [ROUTe:]CLOSe (@*ccmmnn*); for multiple channels use [ROUTe:]CLOSe (@*ccmmnn*,*ccmmnn*,...) or any combination. Closure order for multiple channels with a single command is not guaranteed.

Channel Range: The RF Multiplexer will accept and execute channel ranges (*ccmmnn*:*ccmmnn*) without generating an error, but the result is to close the last channel in each bank within the range specified. For example, after CLOSe (@010101:010151) is executed, card 01, module 01 channels 03, 13, 23, 33, 43, and 51 would remain closed.

Module Number: The module number can be omitted when Expander modules are not connected to the RF Multiplexer. Module numbers must be specified when one or more Expander modules are connected to the RF Multiplexer module.

Related Commands: [ROUTe:]OPEN?, [ROUTe:]CLOSe?

***RST Condition:** All banks with channel 0 connected to COMmon.

Example Closing RF Multiplexer Channels

This example closes channels 100 and 202 of a two-card switchbox (card numbers 01 and 02).

```
CLOS (@101,202)          !101 connects channel 01 to
                         !COM00 on card #1 and 202
                         !connects channel 02 to COM00
                         !on card #2.
```

[ROUTe:]CLOSe?

[ROUTe:]CLOSe?<*channel_list*> returns the current state of the channel(s) queried. *channel_list* has the form (@*ccmmnn*) (see [ROUTe:]CLOSe for definition). The command returns 1 if channel(s) are closed or returns 0 if channel(s) are open.

Comments

Query is Software Readback: The [ROUTe:]CLOSe? command returns the current software state of the channel(s) specified. It does not account for relay hardware failures. A maximum of 127 channels at a time can be queried for a multi-module switchbox.

Example Query Channel Closure

This example closes channels 01 and 02 of a two-module switchbox (card number 01, module 00 and 01) and queries channel closure. Since the channels are programmed to be closed, 1,1 is returned.

```
CLOS (@10001,10102)      !Connect channel 01 to COM00 on
                         !the RF Multiplexer module (00)
                         !and channel 02 to COM00 on the
                         !Expander module (01).
CLOS? (@10001,10102)     !Query module 00 - channel 01
                         !and module 01 - channel 02
                         !closure state.
```

[ROUTe:]OPEN?

[ROUTe:]OPEN?<*channel_list*> returns the current state of the channel(s) queried. *channel_list* has the form (@*ccmmnn*) (see [ROUTe:]CLOSe for definition). The command returns 1 if channel(s) are open or returns 0 if channel(s) are closed.

Comments

Query is Software Readback: The ROUTe:OPEN? command returns the current software state of the channels specified. It does not account for relay hardware failures. A maximum of 127 channels at a time can be queried for a multi-module switchbox.

Example Query Channel Open State

This example closes channels 01 and 02 of a single card two-module switchbox (card number 01, module 00 and 01) and queries channel closure. Since the channels are programmed to be closed, 0,0 is returned.

```
CLOS (@10001,10102)          !Connect channel 01 to COM00 on
                             !the RF Multiplexer module (00)
                             !and channel 02 to COM00 on the
                             !Expander module (01).
OPEN? (@10001,10102)         !Query module 00 - channel 01
                             !and module 01 - channel 02 open
                             !states.
```

SYSTem

The SYSTem subsystem returns the error numbers and error messages in the error queue of a switchbox, and returns the types of descriptions of cards and modules in a switchbox.

Subsystem Syntax

```
SYSTem
    :CDEScription? <number>
    :COPT? <number>
    :CPON <number> |ALL
    :CTYPe? <number>
    :ERRor?
```

SYSTem:CDEScription?

SYSTem:CDEScription?<*number*> returns the description of a selected card in a switchbox.

Parameters

Name	Type	Range of Values	Default Value
<*number*>	numeric	01 to 99	N/A

Comments

RF Multiplexer Module Description: The SYSTem:CDEScription? <*number*>command returns: “Hex 4:1 75 Ohm RF Mux” or “Hex 4:1 50 Ohm RF Mux”.

Example

Reading the Description of Card #1 Module

```
SYST:CDES? 1                    !Return the description
```

SYSTem:COPTion?

SYSTem:COPTion? <*number* > returns the number of Expander Modules connected to a selected RF Multiplexer (card) in a switchbox.

Parameters

Name	Type	Range of Values	Default Value
<*number*>	numeric	01 to 99	N/A

Comments

RF Multiplexer/Expander modules installed: The SYSTem:COPTion? <*number*> command returns:

E1472A,E1473A,E1473A or E1474A,E1475A,E1475A

where the E1472A and E1474A are the RF Multiplexer modules, and the E1473A,E1473A or E1475A,E1475 indicates that two expander modules are connected. A “0” in place of the “E1473” or “E1475” indicates that the Expander module(s) are not installed.

Example

Reading the Model Number of Card #1 Module

```
SYST:COPT? 1                    !Return the module configuration
                                !for card 1
```

SYSTem:CPON

SYSTem:CPON <*number*> **|ALL** sets the selected module (card) in a switchbox to its power-on state.

Parameters

Name	Type	Range of Values	Default Value
<*number*>	numeric	01 to 99 | ALL	ALL

Comments

RF Multiplexer Module Power-On State: The power-on state is all channels (relays) open. Note that SYSTem:CPON ALL and *RST connects X0 to COM X0 in all banks of all modules in a switchbox, while SYSTem:CPON <*number*> connects X0 to COMX0 in only the module (card) specified in the command.

Example

Setting Card #1 Module to Power-On State

```
SYST:CPON 1                     !Sets card #1 to power-on state
```

SYSTem:CTYPe?

SYSTem:CTYPe? <*number*> returns the card type of a selected module in a switchbox.

Parameters

Name	Type	Range of Values	Default Value
<*number*>	numeric	01 to 99	N/A

Comments

RF Multiplexer Module Model Number: The SYSTem:CTYPe? <*number*> command returns (for both modules):

HEWLETT-PACKARD,E1472A,0,A.01.00 or
HEWLETT-PACKARD,E1474A,0,A.01.00

where the 0 after E1472A or E1474A is the module serial number (always 0) and A.01.00 is an example of the module revision code number.

Example

Reading the Model Number of Card #1 Module

```
SYST:CTYP? 1
!Return the model number
```

SYSTem:ERRor?

SYSTem:ERRor? returns the error numbers and corresponding error messages in the error queue of a switchbox. See Appendix C for a listing of switchbox error numbers and messages.

Comments

Error Numbers/Messages in the Error Queue: Each error generated by a switchbox stores an error number and corresponding error message in the error queue. The error message can be up to 255 characters long.

Clearing the Error Queue: An error number/message is removed from the queue each time the SYSTem:ERRor? command is sent. The errors are cleared first-in, first-out. When the queue is empty, each following SYSTem:ERRor? command returns 0, “No error”. To clear all error numbers/messages in the queue, execute the *CLS command.

Maximum Error Numbers/Messages in the Error Queue: The queue holds a maximum of 30 error numbers/messages for each switchbox. If the queue overflows, the last error number/message in the queue is replaced by -350, “Too may errors”. The least recent error numbers/messages remain in the queue and the most recent are discarded.

***RST Condition:** *RST does not clear the error queue.

Example

Reading the Error Queue

```
SYST:ERR?                    !Query the error queue, read and
                             !print the numbers/message
```

Common Commands Quick Reference

The following table lists the IEEE 488.2 Common (*) Commands that can be executed by the RF Multiplexer module. The operation of some of these commands is described in Chapter 3 of this manual. For more information on Common Commands, see the appropriate command module user's guide or the ANSI/IEEE Standard 488.2-1987.

Command	Title	Description
*CLS	Clear status register	Clears all Event Registers, the Request for OPC flag, and all Queues (except output queue).
*ESE *<mask>*	Event status enable	Sets bits in the Event Status Enable Register.
*ESE?	Event status enable query	Queries current contents in Event Status Enable Register.
*ESR?	Event status register query	Queries and clears contents in Standard Event Status Register.
*IDN?	Identification query	Returns identification string of the switchbox.
*OPC	Operation complete	Sets the Request for OPC flag when all pending operations have completed. Sets OPC bit in Standard Event Register.
*OPC?	Operation complete query	Returns a 1 to the output queue when all pending operations have completed. Synchronize between multiple instruments.
*RCL *<n>*	Recall saved state	Recalls previously stored RF Multiplexer configuration. *<n>*(0 to 9) is the location in memory where the desired (previously stored) set-up is located.
*RST	Reset	Connects channel 0 to COM 0 on all banks.
*SAV *<n>*	Save state	Stores the present RF Multiplexer configuration in memory. Stores present settings of the channel states. <n> (0 to 9) is location in memory where the current set-up is to be stored.
*SRE *<mask>*	Service request enable	Used to set the Service Request Enable Register bits and corresponding Serial Poll Status Byte Register bits to generate a service request.
*SRE?	Service request enable query	Query current contents in Service Request Enable Register.
*STB?	Read status byte query	Queries the current contents in the Status Byte Register.
*TRG	Trigger	Not applicable.
*TST?	Self-Test query	Returns +0 if self test passes. Returns +cc01 for firmware error. Returns +cc02 for bus error (communications problem with card). Returns +cc03 for bad ID information. Returns +cc10 if an interrupt was expected but not received. Returns +cc11 if the busy bit was not held ≈9 to 17 msec.
*WAI	Wait to Continue	Halts execution of commands and queries until the No Operation Pending message is true.

SCPI Commands Quick Reference

The following table lists the SCPI commands that can be executed by the RF Multiplexer module. The operation of these commands is described in Chapter 3.

Command Subsystem	Command/Parameter	Description
[ROUTe:]	CLOSe *<channel_list>* CLOSe? *<channel_list>* OPEN? *<channel_list>*	Close Channel(s) Query Channel(s) closed Query channel(s) opened
SYSTem	:ERRor?	Returns error number/message in a switchbox Error Queue.
	CDEScription? *<number>*	Returns description of module in a switchbox.
	CTYPe? *<number>*	Returns the module type.
	:COPTion? *<number>*	Returns the RF Multiplexer/Expander module configuration.
	:CPON *<number>*|ALL	Sets specified module to its power-on state.

Notes:

Appendix A
RF Multiplexer Specifications

Specification	50 Ohm RF Multiplexer	75 Ohm RF Multiplexer
Input Characteristics		
Maximum Voltage	42V peak (any center or chassis to any other center or chassis)	42V peak (any center or chassis to any other center or chassis)
Maximum Current per channel or common	1A DC or AC RMS	1A DC or AC RMS
Maximum Power per channel or common	24 W or 24 VA	24 W or 24 VA
AC Performance		
Insertion Loss (dB)	(Z_L=Z_S=50 Ω) (40°C, 95% RH) <10 MHz < 0.1 <100 MHz < 0.4 <500 MHz < 0.9 <1.3 GHz < 1.5 <3 GHz < 8.0 typical	(Z_L=Z_S=75 Ω) (40°C, 95% RH) <10 MHz < 0.3 <100 MHz < 0.4 <500 MHz < 0.8 <1.3 GHz < 1.0
Crosstalk (dB) (channel-channel[1], or channel-common)	<10 MHz < -90 <100 MHz < -80 <500 MHz < -65 <1.3 GHz < -50 <3 GHz < -20 typical	<10 MHz < -85 <100 MHz < -75 <500 MHz < -65 <1.3 GHz < -45
VSWR	<10 MHz < 1.05 <100 MHz < 1.15 <500 MHz < 1.25 <1.3 GHz < 1.35 <3 GHz < 1.5	<10 MHz < 1.05 <100 MHz < 1.15 <500 MHz < 1.25 <1.3 GHz < 1.35
Risetime	<300 psec	<300 psec
Signal Delay	<3 nsec	<3 nsec
DC Performance		
Thermal Offset	< 6 μV	< 6 μV
Closed Channel Resistance	< 1Ω (typical)	< 1Ω (typical)
Insulation Resistance (any terminal to any terminal)	≤(40°C, 65% RH) = > 10^8Ω	≤(40°C, 65% RH) = > 10^8Ω
General		
Relay Type	Non-latching armature relays	Non-latching armature relays
Typical Relay Life (operations)	With No Load: 5 x 10^6 With Maximum Rated Load: 10^5	With No Load: 5 x 10^6 With Maximum Rated Load: 10^5
Maximum Expander Module Cable Length	8 Meters (for E1473A)	8 Meters (for E1475A)

1 With one channel closed. Specifications valid at front panel SMB connectors without cables or adapters attached.

Notes:

Appendix B
Register-Based Programming

About This Appendix

This appendix contains the information you can use for register-based programming of the RF Multiplexers. The contents include:

- Addressing the Registers 51
- Reading the Registers 52
- Writing to the Registers 53
- Selecting Channels Using Your Own Relays 57

Addressing the Registers

The RF Multiplexer module is a register-based device. To read or write to specific registers, you must use the command register address. Complete command register address is determined by:

- The address space (determined by the command module and mainframe used)
- The module address (determined by the command module used and the module's logical address switch)
- The register offset (for the desired register).

Example: Addressing a Status/Control Register

This example shows how to address the Status/Control Register of an RF Multiplexer module in a C-Size VXI mainframe using an E1406 Command Module. Register addresses for modules are in address space VXI A16. The location of A16 within the E1406 Command Module starts at ($1F0000_h$) ($_h$ = HEX).

The A16 space is divided so modules are addressed only at locations beginning with $C000_h$ within A16. Allocated for each module are 64 register addresses (40_h). The module base address is related to the logical address set by the module's logical address switch (LADDR). The module address is:

$$\text{module address}_h = (\text{logical address}_h) * 40_h + C000_h$$

For the RF Multiplexer module, the default logical address is 120 (78 h), so the module address within A16 = $78_h * 40_h + C000_h = DE00_h$

The Status/Control Register offset is 04 h (from below), so the command register address is:

$$[\text{address space}]_h + [\text{module address}]_h + [\text{register offset}]_h = 1F0000_h + DE00_h + 04_h = 1FDE04_h$$

Reading the Registers

You can read the following RF Multiplexer registers:

- Manufacturer ID Register (base+0_h)
- Device Type Register (base+0_h)
- Status/Control Register (base+04_h)
- Remote Module Register (base+06_h) [Module 00 status]
- Remote Module Register (base+08_h) [Module 01 status]
- Remote Module Register (base+$0A_h$) [Module 02 status]

- Module 00 Bank 00-02 Channel Enable Register (base+10_h)
- Module 00 Bank 03-05 Channel Enable Register (base+12_h)
- Module 01 Bank 00-02 Channel Enable Register (base+14_h)
- Module 01 Bank 03-05 Channel Enable Register (base+16_h)
- Module 02 Bank 00-02 Channel Enable Register (base+18_h)
- Module 02 Bank 03-05 Channel Enable Register (base+$1A_h$)

Manufacturer ID Register

Reading this register returns $FFFF_h$. This shows Hewlett-Packard is the manufacturer and the module is an A16 register-based device.

Device Type Register

Reading this register returns 0180_h if the device is the E1474A RF Multiplexer module, with or without Expander module(s) connected. The E1474A/E1475A use the same Device ID as the E1472A/E1473A. However, the relay module will generate a different remote module code to distinguish between the modules (see “Remote Module ID Registers” in this appendix).

Status/Control Register

The Status/Control Register informs the user about the modules status. Each relay requires about 15 msec execution time during which time the RF multiplexers are “busy”. Bit 7 of this register is used to inform the user of a “busy” condition.

In addition, the interrupt generated after a channel has been closed can be disabled. Bit 6 of this register is used to inform the user of the interrupt status. A read of the Status/Control register (base+04_h) returns:

- $FFBF_h$ when the module is not busy and interrupt is enabled.
- $FF3F_h$ when the module is busy and interrupt is enabled.
- $FFFF_h$ when the module is not busy and interrupt is disabled.
- $FF7F_h$ when the module is busy and interrupt is disabled.

Remote Module ID Registers

Reading these registers determines the number and location of E1473A and E1475A Expander modules connected to E1472A and E1474A RF Multiplexers.

Module 00 Status: The base $+06_h$ register returns module 00 status (RF Multiplexer relays connected to the RMD0/1 connector). Returns $FF11_h$ if the relays are connected, and $FFFF_h$ if the relays are not connected. Returns $FF00_h$ if E1472A/E1473A modules are connected. If you are using the E1474A to control additional E1473A or E1475A modules, use this register to verify the relay type.

Module 01 Status: The base $+08_h$ register returns module 01 status (Expander module connected to the RMD2/3 connector). Returns $FF11_h$ if a module is connected, and $FFFF_h$ if a module is not connected. Returns $FF00_h$ if E1472A/E1473A modules are connected. If you are using the E1474A to control additional E1473A or E1475A modules, use this register to verify the relay type.

Module 02 Status: The base $+0A_h$ register returns module 02 status (Expander module connected to the RMD4/5 connector). Returns $FF11_h$ if a module is connected, and $FFFF_h$ if a module is not connected. Returns $FF00_h$ if E1472A/E1473A modules are connected. If you are using the E1474A to control additional E1473A or E1475A modules, use this register to verify the relay type.

Channel Enable Registers

A read of the Channel Enable register (base $+10_h$ to $1A_h$) always returns $FFFF_h$, regardless of the channel states.

Writing to the Registers

You can write the following RF Multiplexer registers:

- Status/Control register (base $+04_h$)
- Module 00 Bank 0-2 Channel Enable register (base $+10_h$)
- Module 00 Bank 3-5 Channel Enable register (base $+12_h$)
- Module 01 Bank 0-2 Channel Enable register (base $+14_h$)
- Module 01 Bank 3-5 Channel Enable register (base $+16_h$)
- Module 02 Bank 0-2 Channel Enable register (base $+18_h$)
- Module 02 Bank 3-5 Channel Enable register (base $+1A_h$)

Status/Control Register

Writes to the Status/Control Register (base $+04_h$) enables you to reset the RF Multiplexer to turn-on conditions (channel 0 to COM 0 on all banks), and disable/enable the interrupt generated when channels are closed. To reset the RF Multiplexer, write a “1” to bit 0 of the Status/Control Register (base $+04_h$).

NOTE *It is necessary to write a "0" to bit 0 after the reset has been performed before any other commands can be programmed and executed.*

To disable the interrupt generated when channels are closed, write a "1" to bit 6 of the Status/Control Register (base $+04_h$).

NOTE *Typically, interrupts are only disabled to "peek-poke" a module. Refer to the operating manual of the command module used before disable the interrupt.*

Channel Enable Registers

Writes to the Channel Enable registers (base $+10_h$ to $1A_h$) enables you to close the desired channel to COMmon (see Figure B-1). For example, write a "1" to bits 3 and 2 of the (base $+12_h$) Module 00 Bank 3-5 Channel Enable register to close channel 33 on the RF Multiplexer Module. All other bits must be set to "0". Only one channel per bank can be closed at a time. Any bit pattern not shown in Table B-1 results in the lowest-numbered channel being closed to COMmon.

Table B-1. Manufacturer ID Register

$b+00_h$	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Write	Undefined															
Read*	Manufacturer ID															

* Returns $FFFF_h$ = Hewlett-Packard A16 only register-based.

Table B-2. Device Type Register

$b+02_h$	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Write	Undefined															
Read	0180_h															

Table B-3. Status/Control Registers

$b+04_h$	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Write*	Undefined									D	Undefined					R
Read**	Undefined								B	D	Undefined					

* R = Switch reset to power-on state (channel 0 to COMmon all banks) by writing (1) in bit #0.
* D = Disable Interrupt by writing (1) in bit #6.
* * B = Status "busy" is (0) in bit #7.
* * D = Status "Interrupt disable" is (1) in bit #6.

Table B-4. Remote Module 00 ID Register

$b+06_h$	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Write	Undefined															
Read*	Module 00 ID															

* Returns $FFFF_h$ when RF Multiplexer relays are not connected.
* Returns $FF00_h$ when E1472A RF Multiplexer relays are connected.
* Returns $FF11_h$ when E1474A RF Multiplexer relays are connected.

Table B-5. Remote Module 01 ID Register

$b+08_h$	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Write	Undefined															
Read*	Module 01 ID															

* Returns $FFFF_h$ when Expander module number 01 is not connected.
* Returns $FF00_h$ when E1473A Expander module number 01 is connected.
* Returns $FF11_h$ when E1475A Expander module number 01 is connected.

Table B-6. Remote Module 02 ID Register

$b+0A_h$	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Write	Undefined															
Read*	Module 02 ID															

* Returns $FFFF_h$ when Expander module number 02 is not connected.
* Returns $FF00_h$ when E1473A Expander module number 02 is connected.
* Returns $FF11_h$ when E1475A Expander module number 02 is connected.

Table B-7. RF Multiplexer Module 00 Banks 0-2 Channel Enable Registers - RMD0(*)

$b+10_h$	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Write*					CH 23	CH22 CH23	CH21	CH20	CH13	CH12 CH13	CH11	CH10	CH03	CH02 CH03	CH01	CH00
Read	Always Returns $FFFF_h$															

* Write “1” closes channel to COMmon (only one channel per bank can be closed at one time). All other to “0”.

Table B-8. RF Multiplexer Module 00 Banks 3-5 Channel Enable Registers - RMD1(*)

$b+12_h$	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Write*					CH53	CH52 CH53	CH51	CH50	CH43	CH42 CH43	CH41	CH40	CH33	CH32 CH33	CH31	CH30
Read	Always Returns $FFFF_h$															

* Write “1” closes channel to COMmon (only one channel per bank can be closed at one time). All other to “0”.

Table B-9. Expander Module 01 Banks 0-2 Channel Enable Registers - RMD2(*)

$b+14_h$	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Write*					CH23	CH22 CH23	CH21	CH20	CH13	CH12 CH13	CH11	CH10	CH03	CH02 CH03	CH01	CH00
Read	Always Returns $FFFF_h$															

* Write “1” closes channel to COMmon (only one channel per bank can be closed at one time). All other to “0”.

Table B-10. Expander Module 01 Banks 3-5 Channel Enable Registers - RMD3(*)

$b+16_h$	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Write*					CH53	CH52 CH53	CH51	CH50	CH43	CH42 CH43	CH41	CH40	CH33	CH32 CH33	CH31	CH30
Read	Always Returns $FFFF_h$															

* Write “1” closes channel to COMmon (only one channel per bank can be closed at one time). All other to “0”.

Table B-11. Expander Module 02 Banks 0-2 Channel Enable Registers - RMD4(*)

$b+18_h$	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Write*					CH23	CH22 CH23	CH21	CH20	CH13	CH12 CH13	CH11	CH10	CH03	CH02 CH03	CH01	CH00
Read	Always Returns $FFFF_h$															

* Write “1” closes channel to COMmon (only one channel per bank can be closed at one time). All other to “0”.

Table B-12. Expander Module 02 Banks 3-5 Channel Enable Registers - RMD5(*)

$b+1A_h$	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Write*					CH53	CH52 CH53	CH51	CH50	CH43	CH42 CH43	CH41	CH40	CH33	CH32 CH33	CH31	CH30
Read	Always Returns $FFFF_h$															

* Write “1” closes channel to COMmon (only one channel per bank can be closed at one time). All other to “0”.

Selecting Channels Using Your Own Relays

Figure B-1 shows the pin-outs for connectors P200 and P400 on the driver portion of the module (see Figure 2-3). Connector P200 has connections for remote relay modules (RMD) 0, 1, and 3. Connector P400 has RMD 2, 4, and 5.

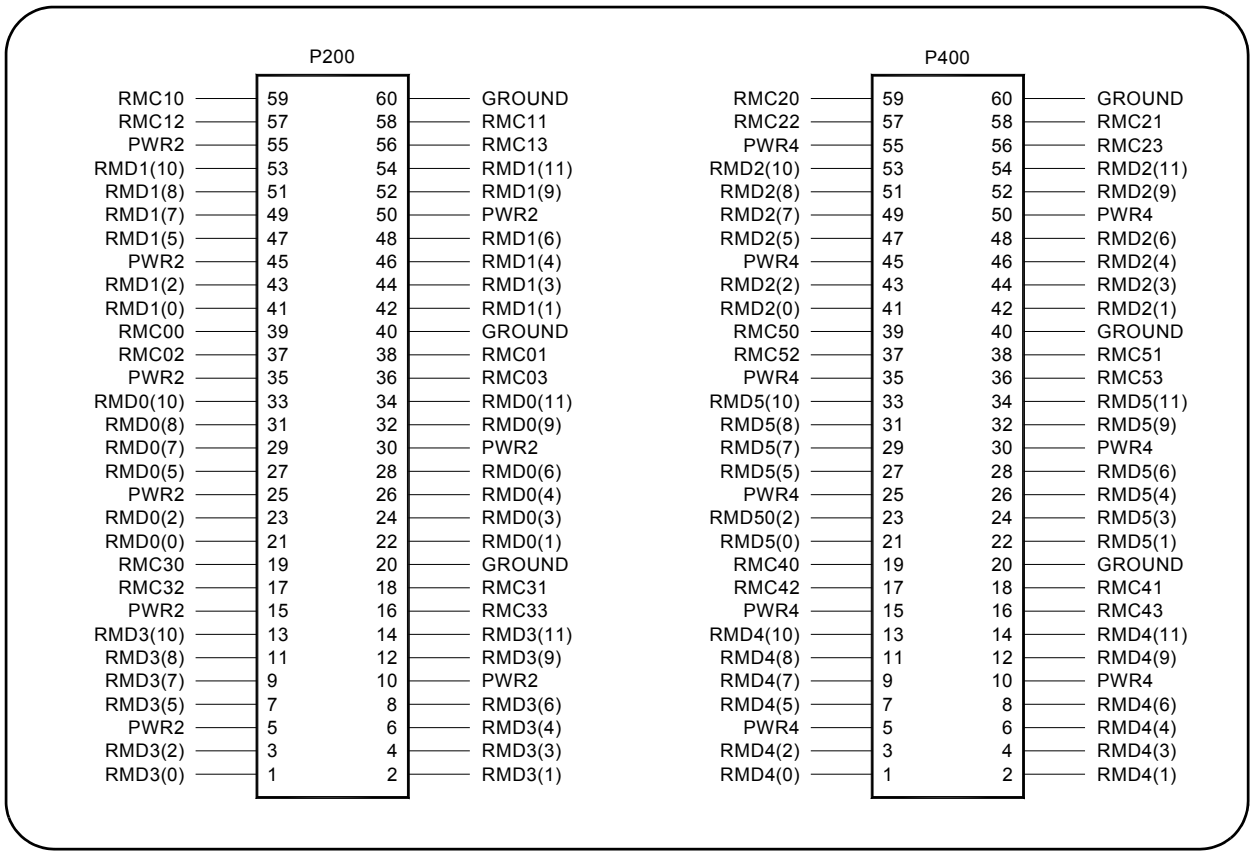

Figure B-1. P200 and P400 Connector Pin-outs

Figure B-2 shows a simplified schematic of a remote relay module (such as RMD,1 for example). P1 connector pins 1, 3, 4, and 5 set the Remote Module Code (RMC). For the 75 Ohm relay modules, the code is $FF11_h$. These pins set the code for RMC00-RMC03, RMC10-RMC13, RMC30-RMC33 on P200 and RMC20-RMC23, RMC40-RMC43, and RMC50-RMC53 on P400.

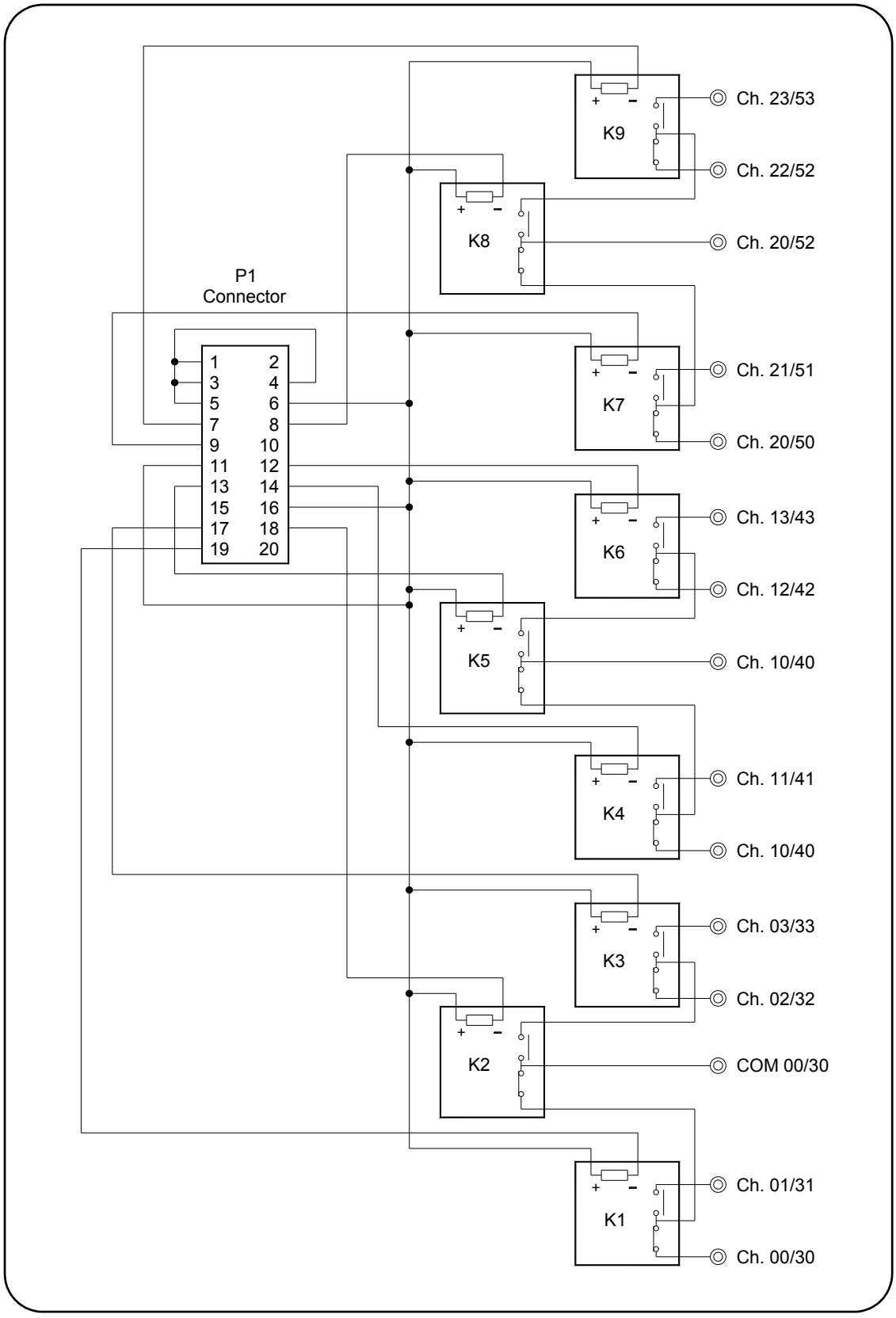

Figure B-2. Relay Module Simplified Schematic

Table B-13 lists the Relay Module P1 connector pins and connection points on P200 and P400.

Table B-13. Connector Pinouts

Relay Module P1 Pins	Pin Names (x is RMD number)	P200 pin numbers			P400 pin numbers		
		RMD0	RMD1	RMD3	RMD2	RMD4	RMD5
1	Ground	60	40	20	60	40	20
2	RMCx0	59	39	19	59	39	19
3	RMCx1	58	38	18	58	38	18
4	RMCx2	57	37	17	57	37	17
5	RMCx3	56	36	16	56	36	16
6	PWR2/PWR4	55	35	15	55	35	15
7	RMDx(11)	54	34	14	54	34	14
8	RMDx(10)	53	33	13	53	33	13
9	RMDx(9)	52	32	12	52	32	12
10	RMDx(8)	51	31	11	51	31	11
11	PWR2/PWR4	50	30	10	50	30	10
12	RMDx(7)	49	29	9	49	29	9
13	RMDx(6)	48	28	8	48	28	8
14	RMDx(5)	47	27	7	47	27	7
15	RMDx(4)	46	26	6	46	26	6
16	PWR2/PWR4	45	25	5	45	25	5
17	RMDx(3)	44	24	4	44	24	4
18	RMDx(2)	43	23	3	43	23	3
19	RMDx(1)	42	22	2	42	22	2
20	RMDx(0)	41	21	1	41	21	1

Example: Using the Register and Pin-out Maps

As an example of using the register information, assume you want to use the E1474 to close a remote 5V relay, K1 (see Figure B-2), connected to the RMD 2 connector (see Figure 2-3). First, change J400 on the driver board to the +5V position (see Figure 2-4).

NOTE *All relays connected through J400 must now be 5 volt relays.*

From the Register maps, Channel 01 on RMD2 is Bit 01. To close channel 01 (relay K1, Figure B-2) on RMD 2 [pin 19 of P1 (corresponds to pin 42 of P400) needs to be at 0 volts to turn on relay K1], send:

```
CLOSE (@010101)
```

or

```
VXI: WRIT ladd,20,2
```

where *ladd* is the logical address of the module.

Appendix C
RF Multiplexer Error Messages

Table C-1 lists the error messages associated with the RF Multiplexer module programmed by SCPI. See the appropriate mainframe manual for a complete list of error messages.

Table C-1. RF Multiplexer Error Messages

Number	Title	Potential Cause
-224	Illegal Parameter	Attempting to execute a command with a parameter not applicable to the command.
2000	Invalid Card Number	Addressing a module (card) in a switchbox that is not part of the switchbox.
2001	Invalid Channel Number	Attempting to address a channel of module in a switchbox that is not supported by the module (e.g., channel 99 of a multiplexer module).
2006	Command not supported on this card	Sending a command to a module (card) in a switchbox that is unsupported by the module.
2009	Too many channels in channel list	Attempting to address more channels than available in the switchbox.
2010	Scan mode not supported on this card	Sending a command to a module (card) in a switchbox that is unsupported by the module.
2600	Function not supported on this card	Sending a command to a module (card) in a switchbox that is not supported by the module or switchbox.
2601	Channel list required	Sending a command requiring a channel list without the channel list.

Notes:

Appendix D
Relay Life

Replacement Strategy

Electromechanical relays are subject to normal wear-out. Relay life depends on several factors. The replacement strategy depends on the application. If some relays are used more often or at a higher load than other relays, the relays can be individually replaced as needed.

If all relays see similar loads and switching frequencies, the entire circuit board can be replaced when the end of relay life approaches. The sensitivity of the application should be weighed against the cost of replacing relays with some useful life remaining.

NOTE *Relays that wear out normally or fail due to misuse should not be considered defective and are not covered by the product's warranty.*

Relay Life Factors

Some effects of loading and switching frequency on relay life follow.

- **Relay Load.** In general, higher power switching reduces relay life. In addition, capacitive/inductive loads and high inrush currents (for example, turning on a lamp or starting a motor) reduces relay life. Exceeding specified maximum inputs can cause catastrophic failure.
- **Switching Frequency.** Relay contacts heat up when switched. As the switching frequency increases, the contacts have less time to dissipate heat. The resulting increase in contact temperature also reduces relay life.

End-of-Life Determination

A preventive maintenance routine can prevent problems caused by unexpected relay failure. The end of life of a relay can be determined by using one or more of three methods: contact resistance maximum value, contact resistance variance, and/or number of relay operations. The best method (or combination of methods), as well as the failure criteria, depends on the application in which the relay is used.

- **Contact Resistance Maximum Value.** As the relay begins to wear out, its contact resistance increases. When the resistance exceeds a predetermined value, the relay should be replaced.
- **Contact Resistance Variance.** The stability of the contact resistance decreases with age. Using this method, the contact resistance is measured several (5-10) times, and the variance of the measurements is determined. An increase in the variance indicates deteriorating performance.
- **Number of Relay Operations.** Relays can be replaced after a predetermined number of contact closures. However, this method requires knowledge of the applied load and life specifications for the applied load.

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